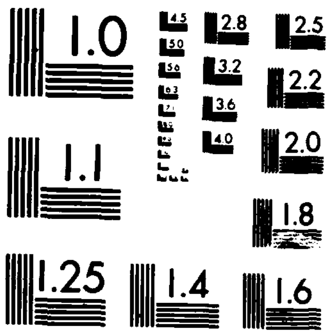
AD-A137 178 SMITHLAND LOCKS AND DAM OHIO RIVER; HYDRAULIC MODEL INVESTIGATION(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS HYD.. J J FRANCO ET AL. OCT 83 1/2

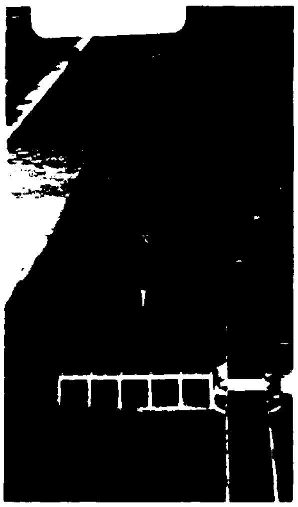
UNCLASSIFIED WES/TR/HL-83-19 F/G 13/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

US Army Corps
of Engineers

AD A137178



TECHNICAL REPORT

SMITHLAND L CKS AND DAM, OHI RIVER

Hydraulic Model Investigation

U S Army ... Station

DTIC

JAN

A

October 1983

Final Report

Approved For Public Release Distribution Unlimited

DTIC FILE COPY

Prepared for U. S. Army Engineer District, Nashville
Nashville, Tenn. 37202

and U. S. Army Engineer District, Louisville
Louisville, Ky. 40201

HYDRAULICS LABORATORY

84 01 24 087

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report HL-83-19	2. GOVT ACCESSION NO. AD-A137178	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SMITHLAND LOCKS AND DAM, OHIO RIVER; Hydraulic Model Investigation		5. TYPE OF REPORT & PERIOD COVERED Final report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John J. Franco Thomas J. Pokrefke, Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Hydraulics Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, Nashville P. O. Box 1070 Nashville, Tenn. 37202 and U. S. Army Engineer District, Louisville P. O. Box 59 Louisville, Ky. 40201		12. REPORT DATE October 1983 13. NUMBER OF PAGES 107 15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Hydraulic models Locks (Waterways) Navigation conditions Smithland Lock and Dam Ohio River		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This investigation was concerned with the development of plans for the Smithland Locks and Dam located on the Ohio River at mile 918.5. The study indicated that satisfactory navigation conditions could be developed with a 17-gate or 11-gate spillway and with a 600- and a 1,200-ft lock or with two adjacent 1,200-ft locks. With two 1,200-ft locks, a new concept in the arrangement of the lock auxiliary walls was

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

developed that would improve navigation conditions, particularly for downbound tows. Ports will be required in the upper guard walls to reduce the tendency for crosscurrents near the ends of the walls. Shoaling in the lower lock approach will be a maintenance problem but could be minimized with the use of wing dikes along the lower end of the lower guard wall.

Developments in the lower reach are affected by divided flow and intermittent flow from the Cumberland River. Dike structures will be required along the right bank downstream of the locks to prevent the channel from meandering and migrating toward the right bank. There will be a tendency for some shoaling in the channel between Cumberland and Towhead Islands approaching the mouth of the Cumberland River, particularly when there is flow to the left of Towhead Island, and reduction in flow in the channel to the left of Cumberland Island.

There will tend to be a greater concentration of flow toward the gate bays near the fixed weir, particularly with the 11-gate spillway, causing a deep scour hole downstream of the gates and shoaling to the left downstream of the fixed weir. Flow through the gates near the fixed weir can be improved by moving the fixed weir about 160 ft upstream of the axis of the dam and tying into the left spillway abutment pier in a curve forming a guide wall.

Scouring will occur near the upper corner and riverside face of the gated spillway cofferdam, but the scouring can be moved away from the cofferdam with a deflector developed during the study. Results also indicated conditions that will exist during various phases of construction.

PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers (OCE), U. S. Army, in the Second Indorsement, dated 6 July 1966, to the U. S. Army Engineer District, Nashville (ORNED), letter of 23 June 1966, subject: Model tests for Smithland Locks and Dam. The study was conducted for ORNED and the U. S. Army Engineer District, Louisville (ORLED), in the Hydraulics Laboratory, U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, intermittently during the period October 1966 to May 1980.

The study was concerned with the development of the project plan and with problems encountered during construction. During the course of the study, ORNED was kept informed of the progress and results of the study through monthly and special reports and by demonstrations of special features of the project.

Periodic visits were made by various representatives of OCE, U. S. Army Engineer Division, Ohio River (ORD), ORNED, and ORLED, during the course of the study to observe and discuss the results of special tests and to discuss plans for future tests. Representatives intimately connected with the model study included: Mr. J. P. Davis, OCE; Messrs. M. P. Mindel, A. J. Moors, G. F. Brown, W. H. Browne, Jr., P. H. Carrigan, and C. L. Humphrey, ORD; Messrs. J. T. Dennison, H. T. Glenn, H. J. Blazek, John Mathewson, Frank P. Gaines, and Herman Gray, ORNED; and Messrs. Jack Skinner, Dave Beatty, and J. R. Bleidt, ORLED.

The investigation was conducted under the general supervision of Messrs. E. P. Fortson, Jr., retired Chief of the Hydraulics Laboratory, and H. B. Simmons, present Chief of the Hydraulics Laboratory, and F. A. Herrmann, Jr., Assistant Chief. Direct supervision was provided by Messrs. J. J. Franco, retired Chief of the Waterways Division, and J. E. Glover, present Chief of the Waterways Division. The engineers in immediate charge of the model study were successively Messrs. J. E. Glover, B. K. Melton, and T. J. Pokrefke, Jr. Mr. L. J. Shows was in direct charge of special tests concerned with navigation conditions. Assisting in conducting the study were Messrs. Allen Hullum,

Lloyd Woods, Ray Emerson, Larry Barnes, Ron Wooley, R. K. Anglin, B. T. Crawford, and D. M. Maggio. This report was prepared by Messrs. Franco and Pokrefke. The report was submitted to the Louisville District for review and comment prior to publication.

Commander and Director of WES during the preparation and publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second
miles (U. S. statute)	1.609344	kilometres

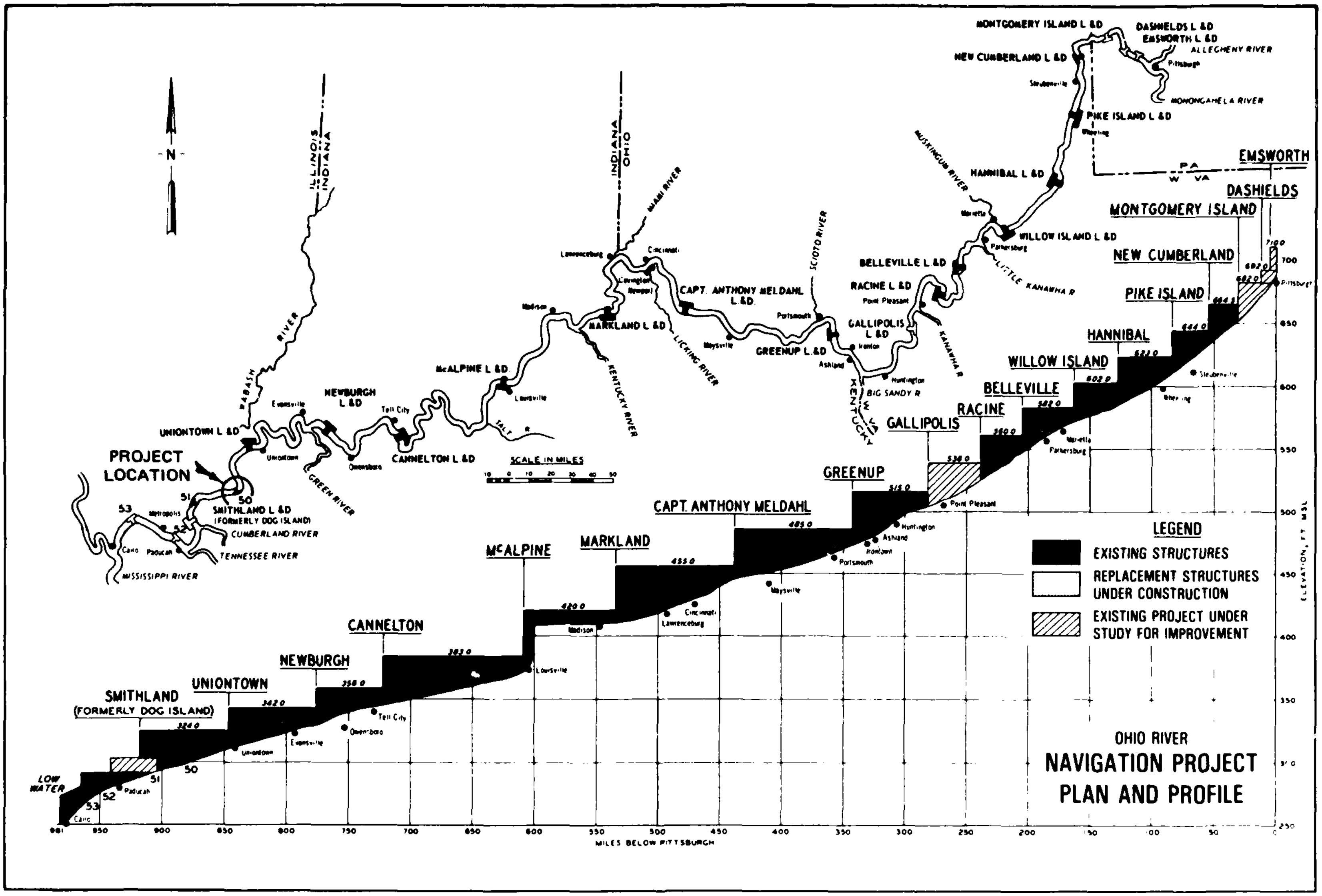


Figure 1. Location map

SMITHLAND LOCKS AND DAM, OHIO RIVER

Hydraulic Model Investigation

PART I: INTRODUCTION

Location and Description of the Prototype

1. Smithland Locks and Dam are being constructed on the Ohio River at mile 918.5 below Pittsburgh, Pennsylvania. The site is about 2 miles* upstream from Smithland, Kentucky, and about 16 miles upstream from Paducah, Kentucky, the largest city in the vicinity (Figure 1). The proposed upper pool of the dam will extend upstream to Uniontown Locks and Dam, a distance of 72.5 miles. The Cumberland River enters the Ohio River about 2 miles downstream of the locks and dam.

2. The Smithland project is in a region of moderate relief. Elevations range from just under 280.0 ft Ohio River Datum** in the main stream channel to about 330.0 in the floodplains. The Ohio River varies from about 1/2 to 1 mile wide in the vicinity of the project site, with a floodplain which is about 2 miles wide near and upstream of the site.

3. The existing navigation project for the Ohio River, authorized by the Rivers and Harbors Acts approved 25 June 1910, 18 July 1918, and 30 August 1935, consists of maintained channels and a system of locks and dams that provide a usable depth of 9 ft. Before modernization of the system was undertaken, the project consisted of 46 structures, each with a chamber 110 ft wide by 600 ft long. At four of the structures, auxiliary locks 56 ft wide by 360 ft long were provided. Most of these dams were of the movable type and were lowered to the riverbed during

---

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 5.

** All elevations (el) cited herein are in feet referred to the Ohio River Datum. To convert from the Ohio River Datum to the National Geodetic Vertical Datum (NGVD), subtract 0.71 ft from the cited elevations.

flood conditions, thereby allowing navigation to proceed over the pass section of the dam. Navigation channel widths generally are in excess of 500 ft, except at critical bars where there is periodic recurrent shoaling. Channels at critical bars are maintained to a width of 300 ft by periodic dredging.

Project Plan

4. Smithland Locks and Dam are part of the Ohio River modernization program and are designed to replace existing Locks and Dam Nos. 50 and 51. The project was approved by the Secretary of the Army on 8 December 1965, under authority of Section 6 of the Rivers and Harbors Act, approved 3 March 1909 as amended. The approved project provides for the construction of a nonnavigable gated-type dam with a fixed-weir section, two locks, acquisition in fee of lands for these structures and reservoir public-use areas, acquisition of flowage easements for navigation pool generally, and necessary remedial works to roads and other utilities required by the increase in pool level.

5. The plan originally proposed had a 17-gate spillway, a 110- by 1,200-ft main lock, and a 110- by 600-ft auxiliary lock. The composition and dimensions of the structures were modified during the course of the investigation as a result of foundation studies and of model studies of the project. The project as finally approved will have two parallel locks, each having a clear chamber size of 110 by 1,200 ft located near the right bank (Illinois) side of the river. The lift of the locks will be 22 ft at normal pools. The dam will consist of a 1,390-ft-long concrete spillway section adjacent to the locks and a 2,260-ft-long fixed-weir section extending from the spillway to the left bank of the river designed to maintain a normal upper pool of 324.0. The spillway section will contain 11 tainter gates 110 ft wide by 36 ft high, an ogee crest at el 290.0 with stilling basin, and concrete piers separating the gates and supporting a concrete service bridge. The fixed-weir section would be constructed of steel sheet-pile cells supporting a concrete cap with top el 326.0.

Purpose of Model Study

6. The Smithland Locks and Dam project involved the investigation of several alternate plans in a rather complex reach of river characterized by islands, divided flow, and rock outcrop. The evaluation of the effects of the various designs on flow conditions, navigation, and movement of sediment by analytical means is extremely difficult and inconclusive. A model investigation was therefore considered necessary to determine the following:

- a. Optimum location and alignment of the locks and arrangement of the lock auxiliary walls.
- b. Navigation conditions in the lock approaches and over the fixed weir with the various plans considered.
- c. Shoaling and erosion tendencies.
- d. Effects of various amounts of rock excavations.
- e. Optimum alignment for the lock lower approach channel and training structures required to eliminate or reduce the need for maintenance dredging.
- f. Effects of various dam modifications.
- g. Conditions that can be expected during construction with various phase cofferdams.
- h. Modifications required to eliminate any undesirable conditions or to improve the efficiency of the project.

The model was also used to demonstrate the conditions that will result from construction of the project for various engineers and operators concerned and to satisfy them as to its acceptability from a navigation standpoint.

PART II: THE MODEL

Description

7. The Smithland Locks and Dam model was a scale reproduction of about 8 miles of the Ohio River extending from about mile 916.5 to about mile 925.0 and included the lower reach of the Cumberland River (Figure 2). The model was constructed initially as a fixed-bed type with provisions for converting a portion of the channel bed upstream and downstream of the proposed damsite to a movable bed. Except for the reach between miles 917.5 and 925.0, the channel bed and overbank areas were molded in sand-cement mortar to sheet-metal templates. The section of the model to be converted to movable bed was molded initially with pea gravel that was later replaced with crushed coal. The structures including the locks and dam and overflow section were constructed of sheet metal. The dam gates were simulated with simple sheet-metal slide gates.

8. The model was constructed in accordance with a special hydrographic and topographic survey made during October 1966 except for some of the overbank areas which were constructed to surveys made in 1953 (Plate 1). The left overbank included in the model extended generally to the bluff line and the right overbank extended to high ground which was sufficient to permit the study of flows up to the maximum navigable flow of 1,075,000 cfs.

Model Appurtenances

9. Water was supplied to the model by a 10-cfs centrifugal pump operating in a circulating system and was measured at the upper end of the model and into the Cumberland River channel by venturi meters. Water-surface elevations were measured by means of 16 piezometers located along the channel (Figure 3) and connected to a centrally located pit. The tailwater elevation was controlled with an adjustable tailgate located at the lower end of the model. A carefully graded rail

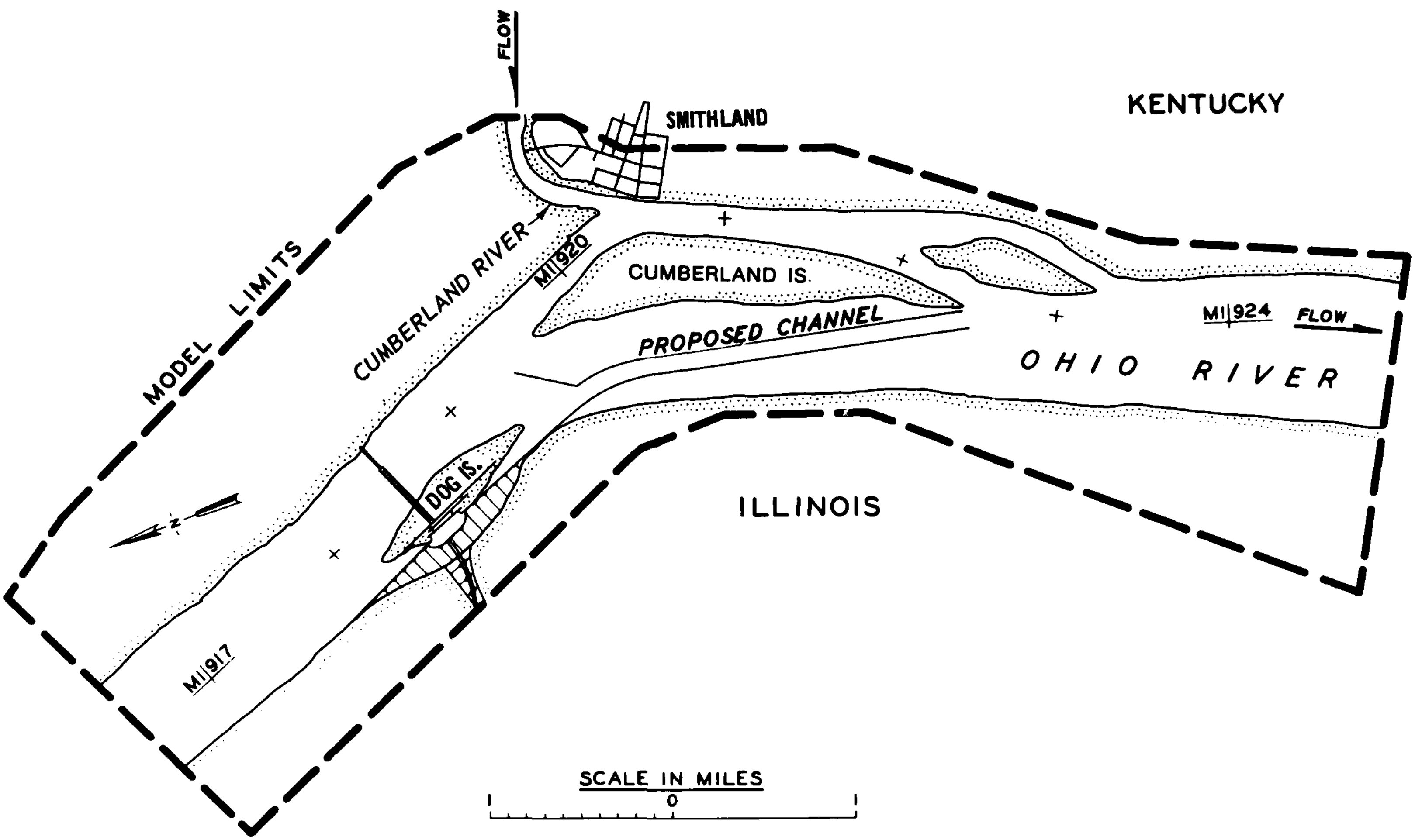


Figure 2. The model

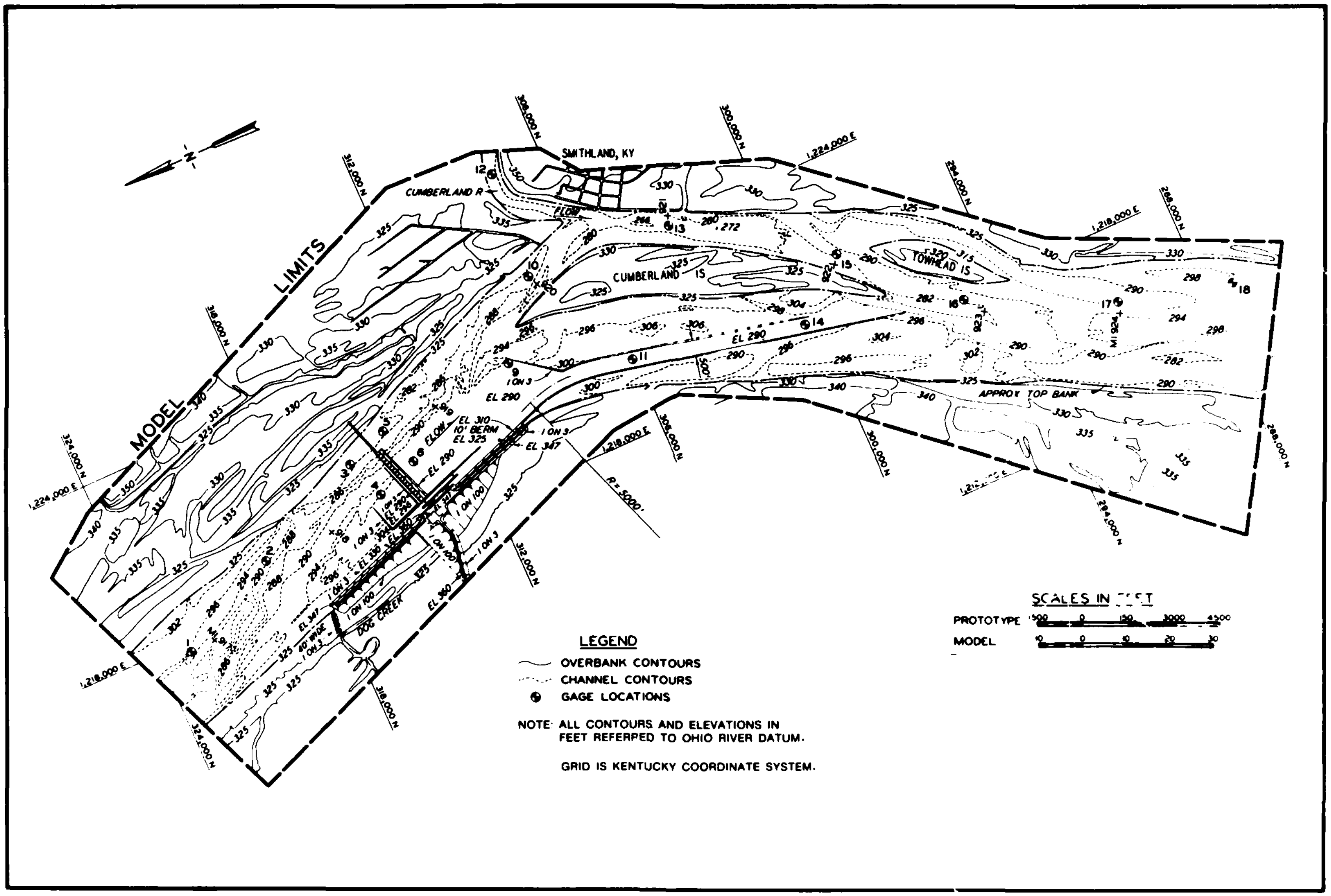


Figure 3. Original design

was located along each side of the channel in the reach to be converted to movable bed. The rails were used to support sheet-metal templates used in molding the model bed and to provide vertical control for surveying the model bed and for installation of training structures. Velocities and current directions were indicated by wooden cylindrical floats submerged to a depth that simulated the draft (9.0 ft) of a loaded barge. Spot velocities were measured by means of a midget current meter.

10. Two model towboats with tows were used to determine the effects of currents on tows approaching and leaving the locks and in negotiating critical reaches (Figure 4). Each towboat was equipped with two screw-type propellers powered by a small electric motor operating from batteries located in the model tow. The power of the towboats was adjusted by means of a rheostat to control its maximum speed in slack water to the comparable speed of towboats normally plying the Ohio River in that reach. The speed of the towboats, set of rudders, and direction (forward and reverse) were remote-controlled.

Scale Relations

11. The model was constructed to an undistorted scale ratio of 1:150, model to prototype, to reproduce accurately velocities, cross-currents, and eddies that would affect navigation. Other scale ratios resulting from the linear scale were as follows:

Area	1:22,500
Velocity	1:12.25
Time	1:12.25
Discharge	1:275,567

The discharge, velocity, and time scales were modified for the movable-bed tests as required to simulate movement of sediment in the reach.

Model Adjustment

12. Model adjustment consisted principally of adjusting the

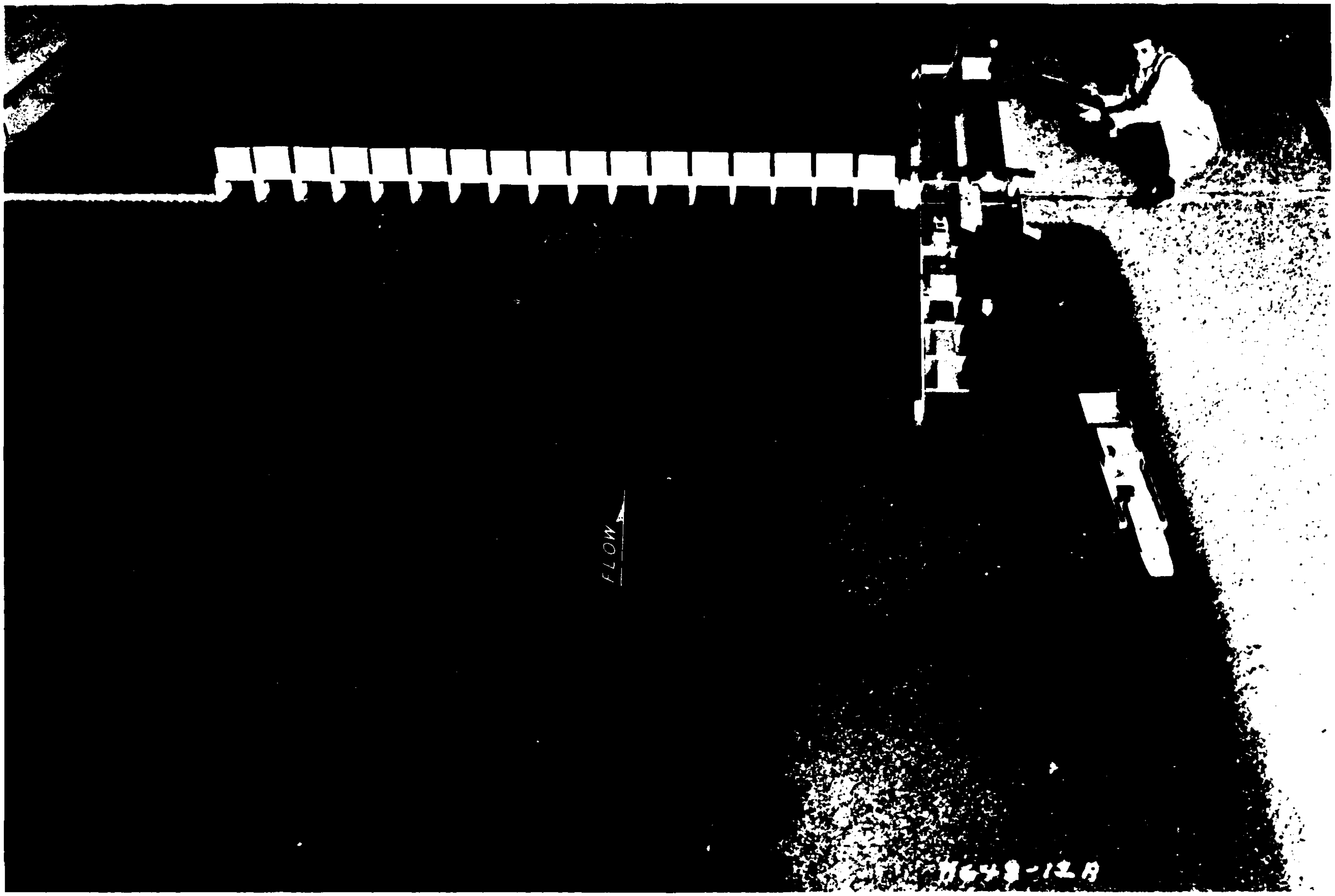


Figure 4. Model towboat and tow

distribution of flow and alignment of currents entering the model channel and overbank based on conditions upstream of the model limits. Screen wire was also placed along the overbank where vegetation was indicated by the data available. Further adjustment of the fixed bed was not considered necessary since small differences in the roughness of the bed between model and prototype would have little effect on water depths and velocities in the short reach and the improvement plan would produce a significant change in conditions in the reach. When the model was converted to movable bed, additional adjustment was required to assure that bed movement was generally similar to that which occurred in that reach of the river. The types of adjustment and the results obtained are covered later in this report.

PART III: FIXED-BED TESTS WITH 17-GATE SPILLWAY

13. Tests with the fixed-bed model were concerned with the study of flow patterns, measurement of velocities in the lock approaches, water-surface elevations, and effects of the currents on the model tow entering and leaving the locks with various flow conditions. These tests were made to determine the adequacy of the proposed plan and to develop modifications that might be required to eliminate any adverse conditions or to increase the efficiency of the project. Tests were also made to determine navigation conditions that would exist during construction with various cofferdam phases in place. No tests were conducted to determine the effects of dam gate operation other than with flow distributed uniformly over the entire length of the spillway, since the worst conditions occurred during the higher river stages with uncontrolled flow.

Test Procedure

14. Tests were conducted by reproducing flows ranging from 50,000 to 1,075,000 cfs, some of which included flow from the Cumberland River. The controlled flows were reproduced by introducing the proper discharges, setting the tailwater elevations for those discharges, and manipulating the dam gate openings until the required upper pool elevation was obtained. All tests with controlled flows were conducted with all the dam gates opened equal amounts. Uncontrolled riverflows were reproduced by introducing the proper discharge with the dam gates fully open and manipulating the tailgate to obtain the proper tailwater elevation below the dam. All flows were permitted to stabilize before any data were taken. Velocities were measured by timing the travel of wooden floats submerged to a depth of 9 ft over a measured distance (usually about 600 ft) and indicate the average velocity over the distance; current directions were determined by plotting the paths of the floats with respect to ranges and grids established for the purpose. Total Ohio River flows reproduced for these tests included the following:

Flow, cfs	Tailwater Elevation
50,000	302.8
100,000	306.0
240,000*	314.3
390,000	322.5
405,000	323.1
427,000	341.5
470,000*	326.0
600,000	331.0
615,000	331.6
750,000*	336.2
760,000	336.1
855,000	338.8
929,000	341.5
1,075,000*	344.0

* Includes 40,000 cfs from Cumberland River.

Original Design

Description

15. The original plan submitted for testing included the following principal features (Figures 3 and 5):

- a. A main lock with clear chamber dimensions of 1,200 by 110 ft located along the right bank on the riverside of an auxiliary lock with clear dimensions of 600 by 110 ft with top of lock walls at el 347.0. The main lock had an upper guard wall 1,240 ft long with 31 ports each 27 ft high by 10 ft wide with top el 317.0 and a 1,120-ft-long solid lower guard wall. The auxiliary lock was provided with a 400-ft-long solid upper guide wall plus a 30-ft end section angled 30 deg landward and a 120-ft-long solid lower guide wall plus a 50-ft end section angled 30 deg landward.
- b. The dam consisted of a gated spillway 2,140 ft long with 17 gate bays each 110 ft wide and eighteen 15-ft-wide piers with crest of the gated spillway at el 285.0, a 1,375-ft-long cell-type overflow section with crest at el 329.0 extending from the left end of the gated spillway to the left overbank, and an embankment extending from the end of the overflow section to high ground with crest at el 334.0. The cell-type overflow section was later reduced to 875 ft and the remainder replaced with an overflow embankment. Areas above and below the

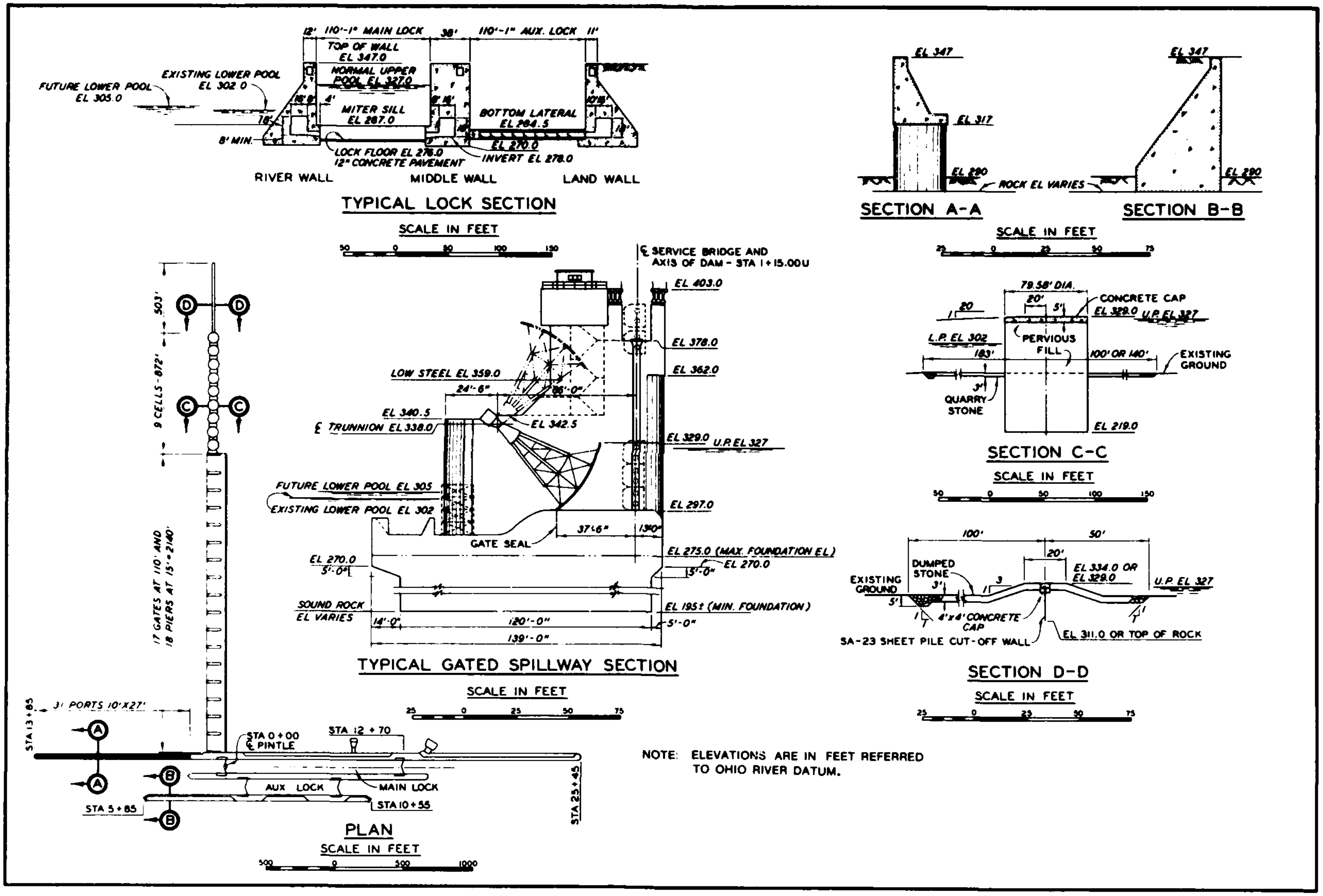


Figure 5. General plan and sections as originally submitted of locks and dam for 17-gate spillway

spillway were excavated to el 296.0 and 290.0, respectively, without regard to top of rock elevation.

c. A dike along the right side of the lock approach channel 355 ft to the right and parallel to the center line of the main lock and extending 4,385 ft upstream of the axis of the dam and 4,115 ft downstream with top at el 347.0.

d. A dredged channel 500 ft wide with bottom at el 290.0 extending from the lower gate sills of the locks to the lower end of Cumberland Island.

Results

16. Results of tests of the original design were as follows:

a. Water-surface elevations. The differences in water-surface elevations were measured between points 800 ft upstream and 630 ft downstream of the gated spillway (gages 4 and 6) and between points 850 ft upstream and 630 ft downstream of the fixed-crest weir (gages 3 and 5). Results of these measurements are listed below:

Discharge at Dam cfs	Difference in Water-Surface El, ft: Gated Spillway	Overflow Weir	Tailwater El*
430,000	1.0	1.7	326.0
710,000	0.7	1.2	336.2
1,035,000	0.4	0.0	344.0

* Tailwater elevation based on average conditions with 40,000-cfs discharge from the Cumberland River.

b. Lower lock approach. Currents in the lower approach moved from the riverside of the lower guard wall toward the right bank across the approach channel (Plates 2-6). Maximum velocities of these currents varied from about 3.6 fps to about 6.9 fps depending on riverflows. Tows moving at extremely slow speed or attempting to drift into or out of the locks would tend to be moved toward and against the right bank by these currents. However, upbound tows could maintain sufficient control to overcome the effects of these currents by approaching some distance from the right bank.

c. Upper lock approach. Currents in the upper lock approach were generally straight except for some disturbance during high stages caused by flow from the right overbank near the end of the dike along the right side of the

approach channel (Plates 3-6). Velocities in the approach were moderate with the maximum varying from about 2.4 fps with the 200,000-cfs flow at the dam to about 5.2 fps with the maximum navigable flow. No serious difficulties were indicated for downbound tows approaching the main lock with the flows tested. Downbound tows approaching the auxiliary lock could experience some difficulties in approaching the guide wall of that lock because of currents moving toward the ports in the guard wall of the riverside lock. The effect of flow from the right overbank during high stages would be a nuisance but was not sufficient to cause tows any serious difficulties, since it occurs far enough upstream where tows can maintain some speed and rudder control.

d. Overflow weir. Currents approaching and passing over the overflow weir were reasonably straight with the 1,035,000-cfs flow at the dam (Plate 6). Maximum velocities approaching the weir varied from 6.5 to 7.1 fps and considerably lower downstream. Maximum velocities of 8.6 to 9.4 fps at the crest appeared to have little effect on upbound tows approaching the weir at normal speed.

e. Ports in upper guard wall. The conditions described above were based on all ports in the upper guard wall open. The effects of closure of some of the ports are shown in Plate 7. These results indicate an increase in the size of the eddy in the lock approach and in the intensity of the crosscurrents as the number of ports were decreased with the maximum navigable flow. Navigation conditions were better with all ports open and tend to be hazardous with every third port closed.

Plans A, A-1, and A-2

Description

17. Plan A and modifications were the same as the original design except for the following (Figure 6):

a. Plan A. The dike along the right side of the upper lock approach channel was rotated by moving its upper end 100 ft landward.

b. Plan A-1. The dike along the right side of the approach channel was moved 50 ft landward and maintained parallel to the center line of the riverside lock.

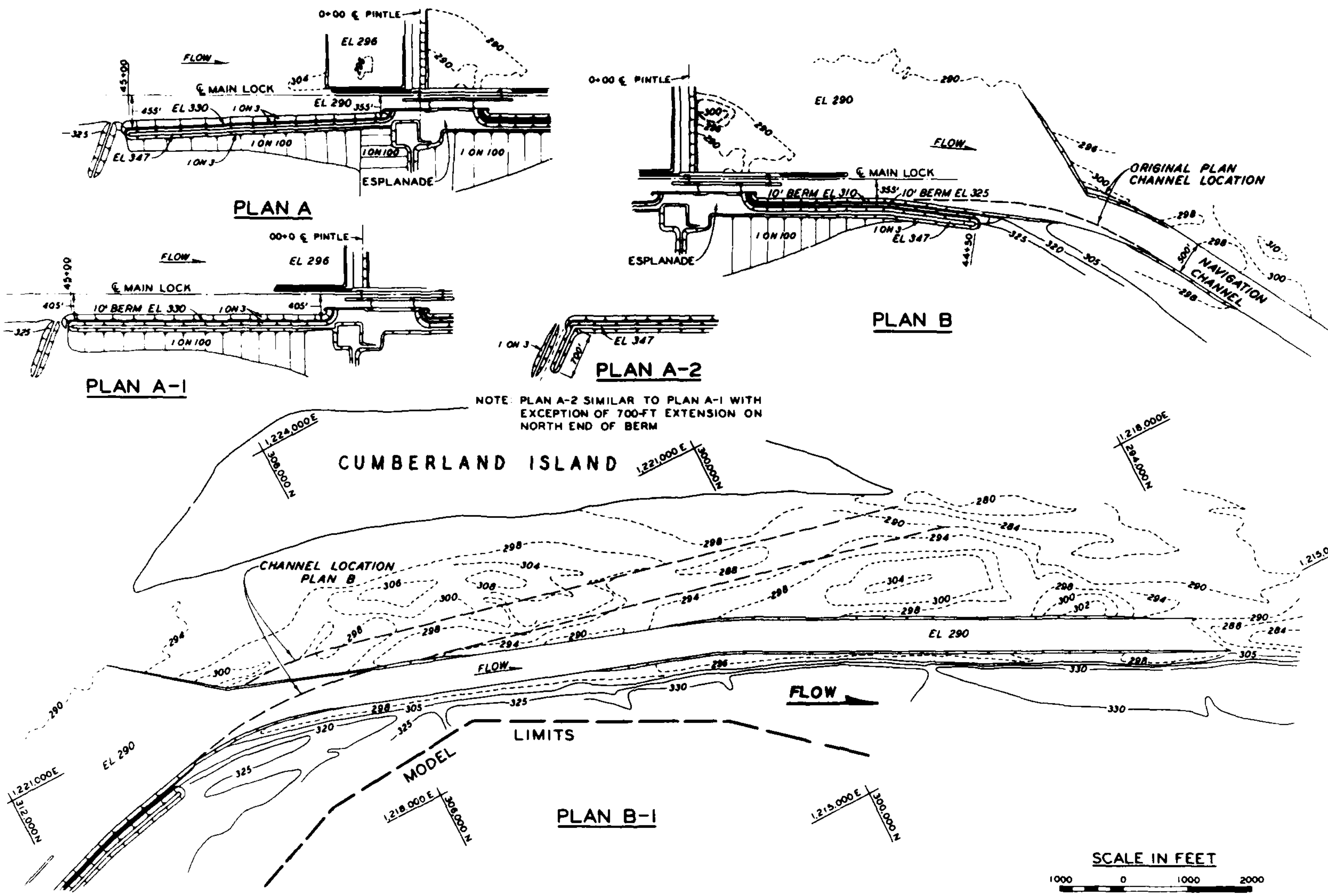


Figure 6. Plans A, A-1, A-2, B, and B-1

c. Plan A-2. Same as Plan A-1 except for a 700-ft extension of the dike along the right bank angled landward and parallel to the realigned Dog Creek channel.

Results

18. Results shown in Plate 8 indicate the following:

a. Changing the alignment of the dike along the right side of the approach channel as in Plan A would tend to affect the alignment of the currents. Navigation conditions with the maximum navigable flow would tend to be less favorable than with the original design because of the change in the alignment of the currents in the approach.

b. Shifting the dike along the right side of the approach channel landward and maintaining it parallel to the upper guard wall of the riverside lock as in Plan A-1 would cause currents to be about the same as those with the original design for the maximum navigable flow. However, navigation conditions would be generally better because of the additional maneuver area, and tows could move closer to the right bank in approaching the locks.

c. Conditions with Plan A-2 were about the same as those with Plan A-1 except that the 700-ft extension on the dike along the right of the approach channel reduced the concentration of flow from the right overbank and reduced the tendency for tows to be moved riverward near the end of the dike.

Plans B and B-1

Description

19. Plan B and modification were the same as the original design except for the following (Figure 6):

a. Plan B. Rock outcrop below the dam was reproduced as indicated by a special survey which in some areas was higher than the dredged areas of the original plan. A portion of the right bank in the lower lock approach was removed, and the dredged channel was realigned. The dike along the right side of the lower approach channel was modified by angling its lower portion landward.

b. Plan B-1. Same as Plan B except that the dredged channel approaching the locks was made parallel to the right bank line.

Results

20. Results of tests of Plan B indicated that leaving the rock outcrop below the dam in place (above el 290.0) would have no measurable effect on water-surface elevations or on navigation conditions with the flows tested. Realignment of the dike along the right side of the lower approach channel and modification of the approach channel reduced the tendency for tows to be moved toward the right bank while approaching or leaving the locks at low speeds (Plate 9). The eddy landward of the lower guard wall obtained with the original design was practically eliminated and tows could be aligned for entrance into the locks with less difficulty.

21. Maintaining the navigation channel below the locks parallel to the right bank line, as in Plan B-1, would provide excellent navigation conditions. Currents were generally parallel to the channel alignment as shown in Plate 10.

Cofferdam Tests--Original Plan

Description

22. Initial plans for the construction of the Smithland project involve the use of a three-stage cofferdam. The first stage would include the construction of the locks and portions of the riverside lock guard walls. The second-stage cofferdam would provide for the construction of 9-1/2 spillway gate bays and a portion of the fixed weir. With this stage cofferdam, riverflow would be diverted through approximately 980 ft of river channel between the riverside lock wall and cofferdam and over about 800 ft of fixed weir at el 329.0 (Plate 11). The third- and final-stage cofferdam would inclose the remaining gate bays and tie in with the riverside lock wall (Plate 12). This would provide 7-1/2 gate bays and about 1,200 ft of fixed weir at el 329.0 available for diversion of streamflow.

23. The cofferdams were constructed of 65-ft-diam cells located on 77-ft centers with top el 341.0 and placed as outlined in Plates 11 and 12. The overburden of Dog Island was removed to el 290.0 or to top

of rock, based on information available at that time. Tests were conducted to determine the differences in water level across the structures and velocities with the 2-, 5-, and 10-year frequency floods with the second- and third-stage cofferdams.

Results

24. The differences in water-surface elevations measured between points 800 ft upstream and 630 ft downstream of the gated spillway and between points 850 ft upstream and 630 ft downstream of the fixed weir were as follows:

Discharge at Dam cfs	Difference in Water-Surface El, ft Gated Spillway 2d Stage	Gated Spillway 3d Stage	Fixed Weir 2d Stage	Fixed Weir 3d Stage	Tailwater El
615,000	5.6	5.1	6.1	5.0	331.6
760,000	4.3	3.9	4.7	3.6	336.1
855,000	4.0	3.5	4.3	2.8	338.8

It should be noted that in the model tests the spillway between the second-stage cofferdam and the locks was in place which would not be the case in the prototype. Had the spillway been removed, the difference in the water level across the structure with the second-stage cofferdam would have been lower than that indicated above. Tailwater elevations used for these tests were based on average conditions with no flow from the Cumberland River. Velocities measured during these tests are shown in Plates 11 and 12. These results indicate that the maximum velocities would occur with the 615,000-cfs flow in the main channel varying from about 18.9 fps with second-stage cofferdam to about 17.8 fps with the third-stage cofferdam. Velocities along the left overbank were generally less than 10 fps except at the crest of the overflow weir. Because of the portion of the spillway in place between the second-stage cofferdam and the locks, velocities in the model would tend to be higher than would be expected in the prototype without the spillway in place.

Plan C

Description

25. Plan C involved the use of two 1,200-ft-long parallel locks and the development of the best arrangement for the lock auxiliary walls. The features of this plan as developed in the model were as follows (Figure 7):

a. Two 1,200- by 110-ft locks separated by a 68-ft-wide intermediate wall with top of walls at el 344.0. Location of the riverward lock was the same as that in Plan B.

b. The upper guard wall of the riverside lock was 1,315 ft long with 35 ports each 27 ft high by 10 ft wide and top el 317.0. A 550-ft-long upper guard wall with 15 ports was on the riverside of the landside lock and a solid guide wall extended 220 ft upstream plus a 50-ft end section angled 30 deg landward. The length of the guide wall on the landside lock was based on design and operational considerations rather than on navigation requirements.

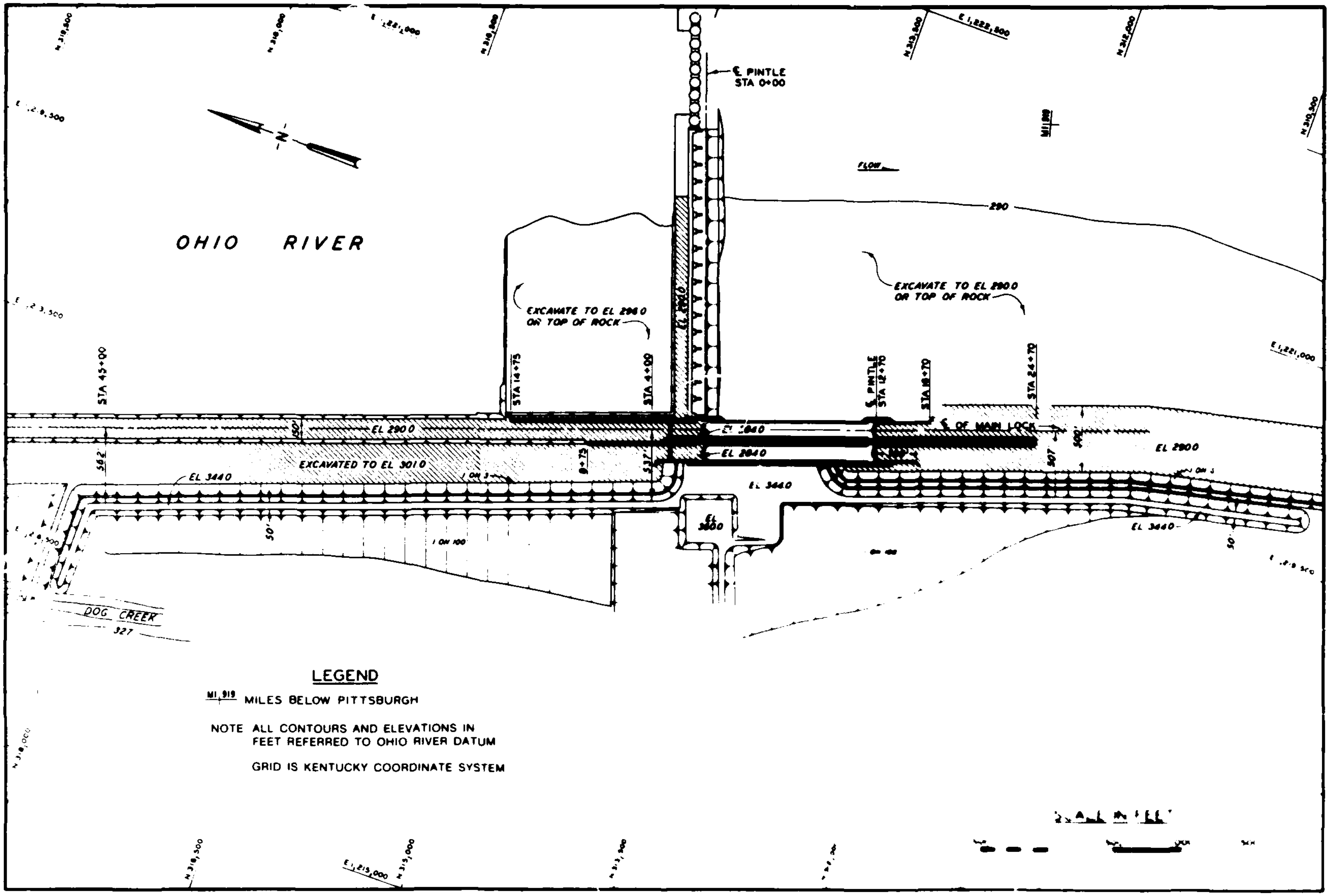
c. A lower guard wall extending 400 ft downstream of the lower gate pintle on the riverside of the riverward lock plus a 50-ft section on the end angled 30 deg riverward, extension of the intermediate wall 1,200 ft downstream of the lower gate pintle to provide a common lower guide wall for the two 1,200-ft locks, and a guide wall extending 300 ft downstream of the lower gate pintle placed on the landside of the landward lock plus a 50-ft end section angled 30 deg landward.

d. Elevation of the dike along the right bank of the upper approach channel included in Plan B lowered to 344.0 and the dike shifted 132 ft landward.

e. Elevation of the dike along the right bank of the lower approach channel included in Plan B lowered to 344.0 and moved landward 30 ft based on the increase in width of the intermediate lock wall.

f. Crest of the overflow section to the left end of the gated dam lowered 3 ft to el 326.0.

The arrangements of the auxiliary lock walls as outlined above were developed during preliminary tests which included the use of a long upper guard wall (riverside) on the riverside lock, a long upper guide wall (landside) on the landside lock, and a long lower guard wall and



F'gure 7. Plan C

lower guide wall on the riverside and landside locks, respectively.

Test results

26. Results of tests of Plan C are as follows:

a. Swellhead. The differences in water-surface elevations at the dam with the two flows tested were as follows:

Discharge at Dam cfs	Difference in Water-Surface El, ft Gated Spillway*	Overflow Weir**	Tailwater El
405,000	0.9	1.3	323.1
600,000	1.0	1.3	331.0

* Gages 4 and 6.
** Gages 3 and 5.

b. Upper lock approach. Preliminary tests with an unported middle wall indicated that downbound tows approaching the upper guide wall on the landward side of the landward lock would experience considerable difficulty in approaching the wall and becoming aligned for entrance into the lock because of the currents moving toward the ports of the guard wall on the riverside lock. Accordingly, ports were added to the middle wall (guard wall on the riverside of the landward lock). With the modifications outlined above, currents in the upper lock approach were generally straight and parallel to the right bank line. Maximum velocities in the upper approach with the flows tested varied from 4.2 fps with the 405,000-cfs flow to 5.8 fps with the 600,000-cfs flow (Plates 13 and 14). There was little or no indication of crosscurrents near the end of the riverside guard wall. The length of the upper guard wall (riverside) was sufficient to permit a 1,200-ft tow to approach the wall without serious difficulty and move along the wall and become aligned for entrance into the riverside lock without any unusual maneuvering. A longer wall produced somewhat better approach conditions and provided a longer target for the approach, but was not considered necessary for a satisfactory approach with the flows tested. Conditions for tows approaching and entering the landside lock were considerably better than with an unported guide wall on the landside of that lock since currents were moving toward the ports in the guard wall rather than away from the guide wall. With Plan C no serious difficulties were indicated for tows approaching the landside lock. However,

a tow approaching the landside lock would tend to have its head moved slowly away from the guard wall by the clockwise eddy near the lower end of the wall when standing or moving slowly without control.

c. Lower lock approach. Currents in the lower lock approach were generally straight, moving from the end of the lower riverside lock guard wall toward the bend in the right bank line at a slight angle to the alignment of the approach channel (Plates 13 and 14). Maximum velocities in the lower approach varied from about 4.1 to 5.6 fps with the flows tested. No serious navigation difficulties were indicated with tows entering or leaving either lock. The common guide wall between the two locks was selected during the tests to provide greater efficiency in the use of the locks. Although no navigation difficulties were indicated with a long guide wall on the landside lock and a long guard wall on the riverside lock, two-way traffic would not be practical within the lock approach. With the long common guide wall between the locks, tows could enter or leave one lock without interfering with tows entering or leaving the other lock. Also, the tendency for shoaling in the lower approach would be less since there would be a more gradual increase in channel width downstream of the locks. Any shoaling that would occur would start in the approach to the riverside lock where it could be removed without interfering with traffic using the landside lock. The only disadvantage attributed to this arrangement was that upbound tows approaching the riverward lock would be moving farther out into the channel in higher velocity currents and would encounter some currents along the guide wall which would require additional power. However, this disadvantage would be more than offset by the elimination of delays caused by tows having to wait to enter or leave either lock when another tow was in or about to enter the lower lock approach.

d. Lock-filling tests. Preliminary tests conducted to determine the effects of lock filling on navigation indicated that filling of a single lock would have little effect on the movement of tows located at least 250 to 300 ft from the lock-filling ports. Currents developed during lock filling would tend to pull tows toward the upper lock gates, with the effects of currents on tows increasing as tows approached the locks. Tows could be pulled away from the guard walls by currents developed by the filling of both locks at the same time. These results have to be considered qualitatively, since lock filling in the model was through the lock gates rather than the lock-filling ports.

PART IV: MOVABLE-BED TESTS WITH 17-GATE SPILLWAY

Model Adjustment and Verification

Procedure

27. Before the model could be used to study the movement of sediment and the shoaling and erosion characteristics of the reach, it had to be adjusted until it reproduced the general tendencies indicated by the available prototype data. Accordingly, the reach of the model between miles 917.5 and 925.0, without the locks and dam, was converted to a movable bed reproduced with crushed coal and molded to the conditions indicated by the prototype survey of October 1966. The model was operated by reproducing the hydrograph recorded in the prototype during the period of November 1965 to October 1966 (Figure 8). During reproduction of the hydrograph, a steady flow of 40,000 cfs was introduced in the Cumberland River channel during portions of the hydrograph based on releases from the Barkley Dam powerhouse. The model was adjusted by varying the discharge scale, rate of introducing bed material, and time scale until the model bed movement appeared to be reasonable for that reach of the river (and the resulting channel configurations were generally similar to those indicated by the only available prototype survey).

Results

28. Results of the final adjustment of the model are shown in Plate 15. A comparison of these results with the prototype survey of October 1966 (Plate 1) indicates that the model as adjusted reproduced with a reasonable degree of accuracy the general configurations and tendencies of the prototype. The model channel between Cumberland Island and Towhead Island tended to be somewhat deeper than the prototype and the channel to the left of Towhead Island to be shallower. This could be attributed to some extent to the distribution of flow around the head of Towhead Island that could have been affected by the condition of the dike at the head of the island which was not known. In spite of these differences and differences of a few feet in other areas,

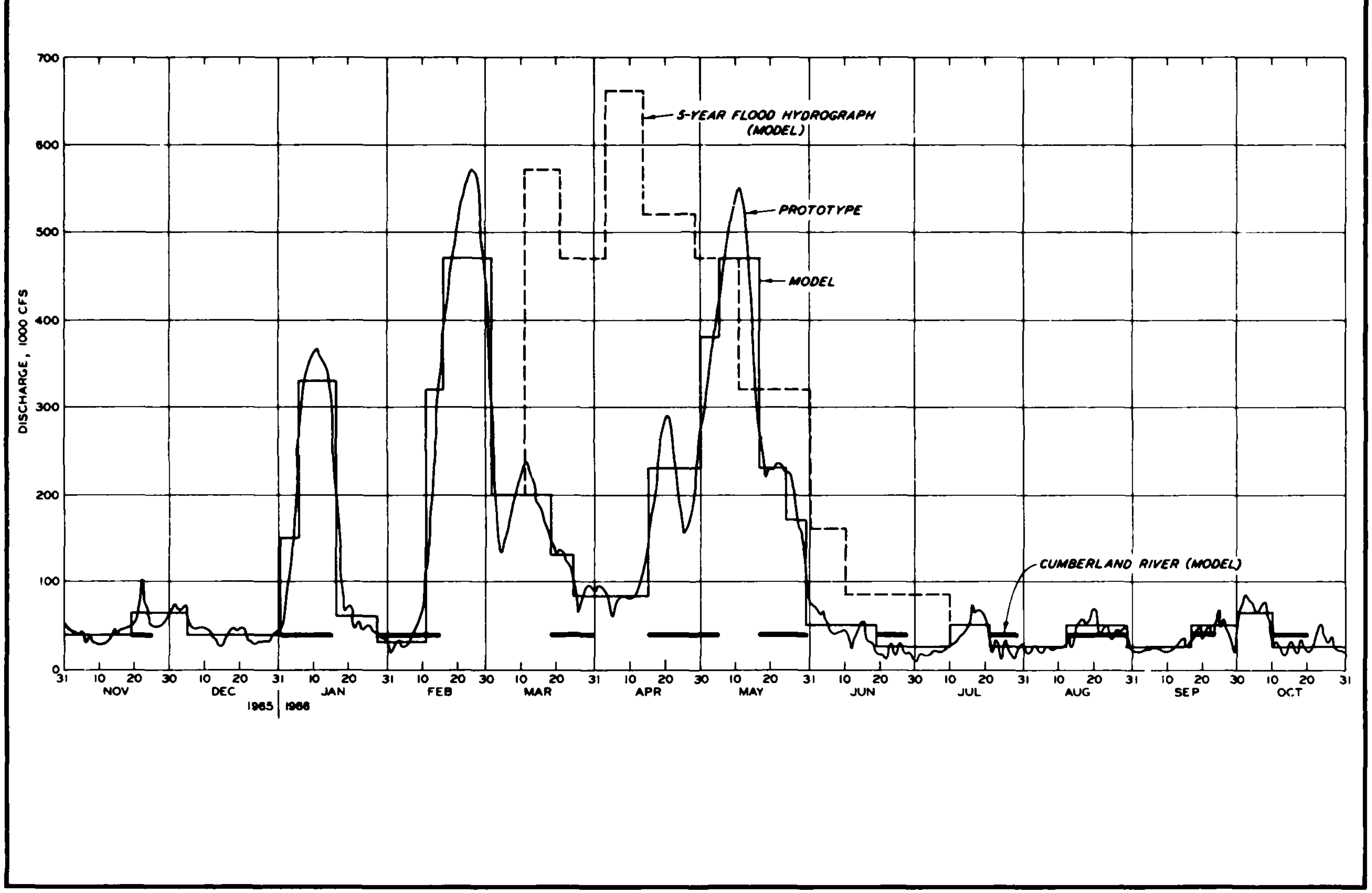


Figure 8. Discharge hydrograph

model adjustment was considered adequate to provide general indications of the tendencies that can be expected with the proposed structures.

Plan D

Description

29. The conditions for Plan D were the same as those for Plan C except for the following (Figures 7 and 9):

- a. Bed of the model was movable instead of fixed except for the rock outcrop.
- b. The length of the ported upper guard wall on the riverside lock was increased 370 ft.
- c. The center lower guide wall was replaced with a long guard wall on the riverside lock extending 1,050 ft below the end of the center wall and a guide wall on the landside of the landside lock extending 450 ft below the end of the center wall.
- d. The 500-ft dredged channel was realigned extending from the lower lock approach to the lower end of Cumberland Island (original design), as shown in Figure 9.

These changes from Plan C were the result of an analysis of previous tests and the U. S. Army Engineer District, Nashville, design considerations. The test was continued for seven runs with each run consisting of the reproduction of the Nov 1965-Oct 1966 hydrograph. The channel in the lower lock approach was maintained by dredging at the end of each run.

Results

30. Results of test of Plan D shown in Plate 16 indicate considerable shoaling in the lower lock approach just downstream of the end of the riverside lock guard wall. The channel downstream of the shoal area increased in depth. The channel along the right side of Towhead Island also increased in depth. A deep scour hole developed downstream of four gate bays adjacent to the fixed weir, and considerable shoaling occurred downstream of the fixed weir which extended toward the dike at the head of Cumberland Island. Shoaling also occurred downstream of the dike and between the right side of Cumberland Island and left side of the

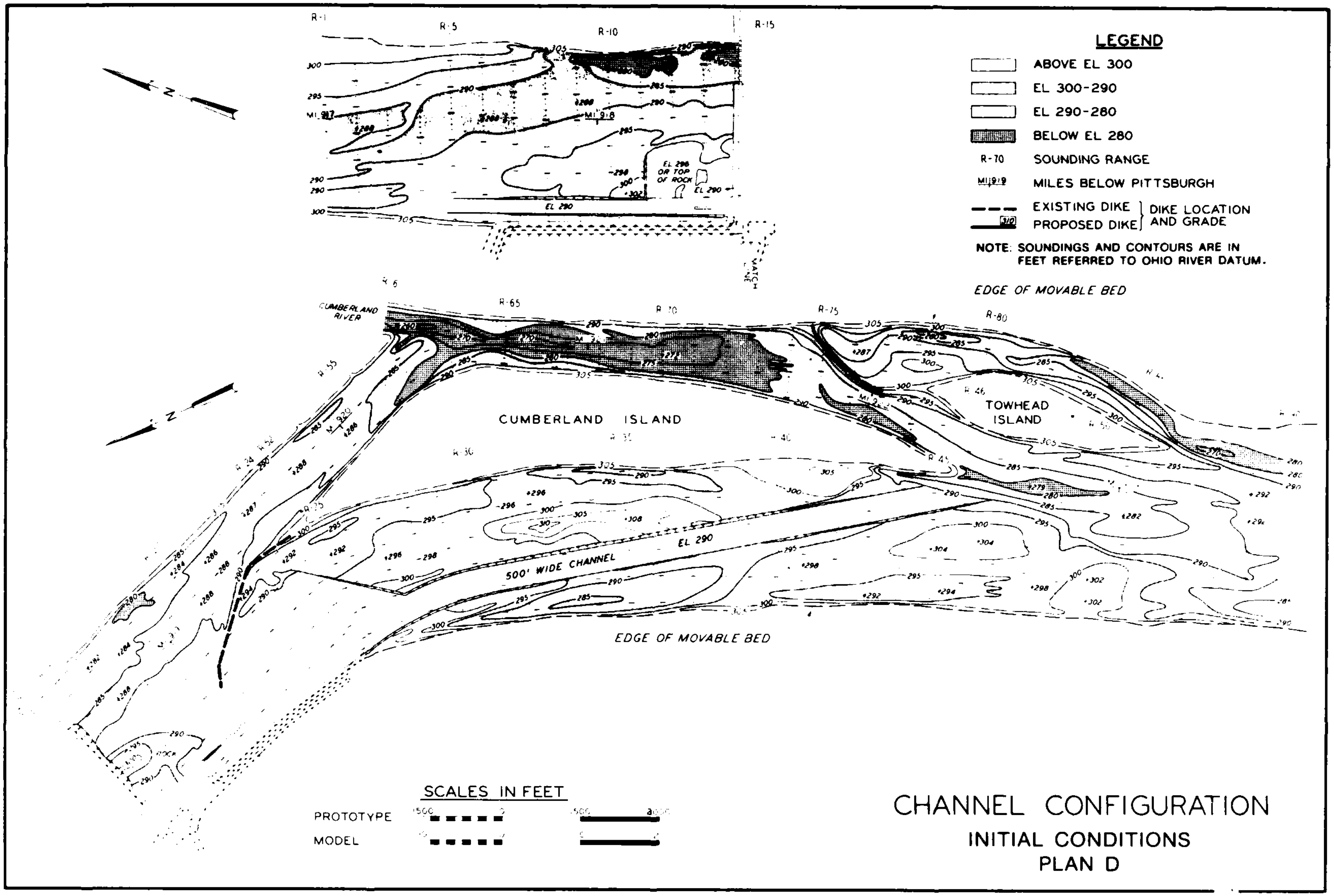


Figure 9. Channel configuration, initial conditions, Plan D

navigation channel. There was little change in the channel from the mouth of the Cumberland River to the main river channel past the head of Towhead Island.

31. Shoaling in the lower lock approach is typical of conditions that can be expected because of the sudden expansion in channel width downstream of the end of the riverside lock wall. Conditions downstream of this shoal were affected to some extent by the shoal area downstream of the fixed weir and by the dike at the head of Cumberland Island which tended to increase the low flows toward and within the dredged channel. Developments in the reach were also affected by the rock outcrop on the right side and downstream of the spillway.

Plans D-1 and D-2

Description

32. Plans D-1 and D-2 were the same as Plan D except for modifications designed to eliminate or reduce shoaling in the lower lock approach. Plan D-1 (Plate 17) included the installation of a 400-ft-long wing dike at the end of the lower guard wall angled riverward 15 deg with crest el 302.0. Plan D-2 (Plate 17) was the same as Plan D-1 except that the crest of the wing dike was raised to el 310.0. Bed conditions at the start of the test of each plan were the same as those obtained at the end of the preceding test except that the shoaling in the lower lock approach channel was removed.

Results

33. Results shown in Plate 17 indicate that the structures at the end of the lower guard wall would produce some reduction in the amount of shoaling but would not be effective in eliminating the need for maintenance dredging. The amount of shoaling was somewhat less with the higher dike of Plan D-2, and a narrow channel was maintained along the right side of the approach channel just downstream of the end of the lower guard wall. The shoaling indicated was based on the results of one reproduction of the annual hydrograph with each plan. Results of these tests also indicated that the navigation channel downstream of the locks tended to migrate toward the right bank.

Plan E

Description

34. Plan E was the same as Plan D-2 except for the installation of six rock dikes along the right bank, as shown in Plate 18. The dikes were designed to reduce the tendency for the navigation channel to migrate toward the right bank and varied in the crest elevation from 317.0 to 306.2, upstream to downstream, to provide a stepped-down effect. The plan was tested with the typical hydrograph (Nov 1965-Oct 1966) and with a 5-year flood hydrograph (Figure 8). The condition of the bed at the start of each test was the same as that obtained at the end of the preceding test except for the removal of the shoaling in the lower lock approach.

Results

35. Results of test of Plan E shown in Plate 18 indicate little change from the results of Plan D. Shoaling in the lower lock approach was greater with the 5-year flood hydrograph than with the typical hydrograph. There was substantial deposition between the dikes along the right bank with little scouring at the ends of the dikes. The flood hydrograph had little effect on the navigation channel in the lower approach downstream of the bend.

Plans F and F-1

Description

36. Plan F was the same as Plan E except for the following (Plate 19):

- a. A 350-ft-long vane dike at el 302.0 was located about 400 ft riverward and 300 ft upstream of the end of the lower lock wall. The dike was angled 15 deg toward the lock wall and designed to divert sediment riverward.
- b. A closure dike was placed across the channel between Cumberland Island and the left bank and located near the upper end of the island. The crest of the dike was at el 310.0.

Plan F-1 was the same as Plan F except that the closure dike at the

head of Cumberland Island was raised to el 320.0.

Results

37. Results shown in Plate 19 indicate some reduction in the amount and elevation of the shoal in the lower lock approach. There was a considerable increase in the depths of the lower approach channel downstream of the shoal area, particularly with Plan F-1. A deep scour hole developed near the right side of the upper end of Cumberland Island with Plan F-1. There was a tendency for some shoaling in the lower end of the channel between Cumberland and Towhead Islands and downstream, particularly with Plan F-1.

Plan G

Description

38. Plan G was the same as Plan E except for the following developed during a number of preliminary tests:

- a. A 150-ft-long curved guide wall with top at el 326.0 extending upstream from the left pier of gate 17. The wall was designed to improve flow through the gates near the left end of the spillway.
- b. A rock dike with crest el 326.0 was placed downstream of the fixed weir with center line 100 ft to the left of the end of the stilling basin and extending 500 ft downstream of the end of the stilling basin and normal to the axis of the dam. The purpose of this structure was to reduce the effect of the eddy forming downstream of the fixed weir and scouring downstream of the left end of the spillway.

Tests of this plan were conducted with and without baffle blocks in the stilling basin. The scour hole downstream of the stilling basin developed during the preceding tests was filled with loose and uncompacted bed material.

Results

39. Modifications of Plan G improved flow conditions and distribution through the spillway particularly through the gates on the left side but had little effect on the depth of the scour hole downstream of the gates on that side. Since there was little change in the bed configuration, the results are not included herein.

PART V: TESTS WITH 11-GATE SPILLWAY

Second-Stage Cofferdam

Description

40. Foundation difficulties discovered since the publication of the general design memorandum and supplement thereto led to the decision to reduce the number of spillway gate bays from 17 to 11 with the fixed weir extended to replace the gate bays removed. Based on this decision, the project was proposed to be constructed in a two-stage cofferdam. The first stage would include construction of the locks and the second stage, the entire 11-gate spillway. Pending the completion of plans for the revised structure, tests were requested to determine conditions with the second-stage cofferdam. The purposes of these tests were to determine the swellhead that would result with the second-stage cofferdam, navigation conditions, scour tendencies, and modifications that would tend to reduce scour near the structure.

41. The cofferdam in the initial plan (Plan A) submitted for testing had its riverward face normal to the axis of the dam located 1,650 ft from the inside face of the riverside lock wall and extended about 232 ft upstream and 372 ft downstream of the axis of the dam. The main cofferdam was constructed of 65-ft-diam sheet-pile cells on 77-ft centers and included a 152-ft curved deflector on the upper end and a 115-ft curved trail section on the lower end of the river face constructed of 25-ft-diam cells.

42. Plan B cofferdam was a modification of Plan A and extended 72.9 ft farther riverward. A deflector consisting of a 145.8-ft upstream extension of the river face of the main cofferdam and a 145.8-ft section angled 45 deg landward at the upper end of the extension replaced the curved deflector used in Plan A (Plate 20). An access road 125 ft upstream of the axis of the dam extended from the left bank line across the floodplain to high ground with top el 331.0. Two 1,200-ft locks with riverside guard walls with a nonoverflow roadway along the right overbank were in place.

43. Plan B-1 was the same as Plan B except that the angled section on the upper end of the 65-ft-diam cell was replaced with a 25-ft-diam cell (Plate 20).

Test procedure

44. Tests were conducted with movable bed except for the rock which was fixed, based on the latest information available. The model was operated by reproducing flows starting with 240,000 cfs and increasing progressively up to the 855,000-cfs flow considered to be the 10-year frequency flood. Each flow reproduced was maintained constant until the bed configuration, particularly in the scour area, was reasonably stable.

Results

45. Scour patterns with Plan A were considered excessive near the cofferdam, and the results are not covered in this report since the plan was modified considerably. Scour patterns developed during Plans B and B-1 are shown in Plate 20. Scouring started near the deflector with the 240,000-cfs flow and increased with increase in discharge. The scour hole reached bedrock (el 220.0) with the 500,000-cfs flow and increased in size as the discharge was increased. There was some shoaling along the river face of the main cofferdam by the end of the 615,000-cfs flow. The lowest elevation measured along the main cofferdam with Plan B was 288.0 with 760,000 cfs and 278.0 with 855,000 cfs; these elevations were obtained near the upper end of the main cofferdam. There was little difference in the results with Plan B-1 except that the lowest elevation with the 855,000-cfs discharge was about 5 ft higher than that with Plan B. Although partially cut out of the short section shown in Plate 20, some scouring of the bed along the left bank was noted in the reach from about 1,200 ft upstream to about 1,200 ft downstream of the axis of the dam. A relatively deep scour occurred along the left bank near the end of the access roadway. This was attributed to flow along the left overbank diverted riverward by the access roadway.

46. The alignment of currents and velocities affecting navigation with Plan B-1 are shown in Plate 21. Except near the cofferdam, currents were generally straight and parallel to the left bank line.

Maximum velocities in the pass between the cofferdam and left bank ranged from about 12 to 13 fps. Tows capable of negotiating the high-velocity currents should experience no serious difficulty in moving through the pass. Downbound tows moving close to the cofferdam would tend to be moved away from the structure by the currents past the deflector. Velocities indicate that some erosion of the left bank could occur in the reach between about 1,500 ft upstream and downstream of the axis of the dam.

47. Water-surface elevations shown in Table 1 indicate the maximum drop through the reach of about 1.3 ft (gages 3-A to 5-A) with the 615,000-cfs flow. Water-surface elevations along the upper arm of the cofferdam were about 341.4 ft (gage 4) with the 855,000-cfs flow.

Effects of Gate Sill Elevations and Rock Excavations

Description

48. Before design of the 11-gate spillway could be finalized, information was required as to the effects of various gate sill elevations and amounts of rock excavations on water-surface elevations. These tests were conducted with the following features (Figure 10):

a. Spillway consisting of eleven 110-ft gate bays with crest at el 290.0 initially and modified during some of the tests, as indicated for Plans D-1 through D-3. Stilling basin at el 270.0 with end sill at el 276.0.

b. An overflow weir (top el 326.0) and embankment (top el 331.0) extending from the end of the spillway to the left overbank. The weir was located 165 ft upstream of the axis of the dam and its right end curved to tie in with the left spillway abutment pier.

c. Excavation upstream (el 285.0) and downstream (el 275.0) of the spillway for Plans A through D are shown in Figure 11.

d. Two 1,200- by 110-ft locks and the lower guide walls in the same configuration as tested in Plan D of the 17-gate structure.

e. The upper guard wall on the riverside lock was 1,685 ft long with 48 ports each 19 ft high by 20 ft wide with top el 309.0. There was a 640-ft-long upper guard wall on

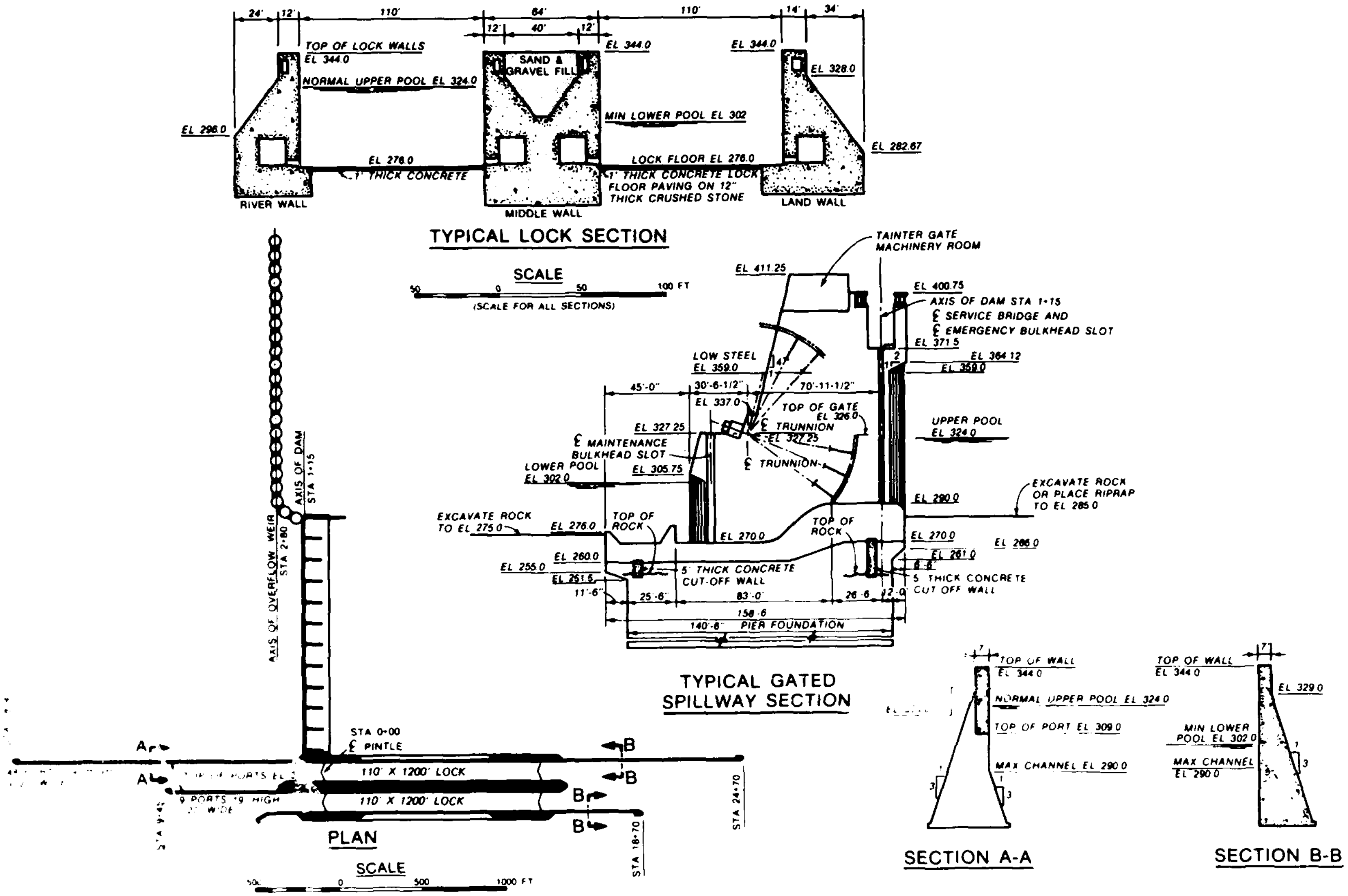


Figure 10. General plan and sections as originally submitted of locks and dam for 11-gate spillway

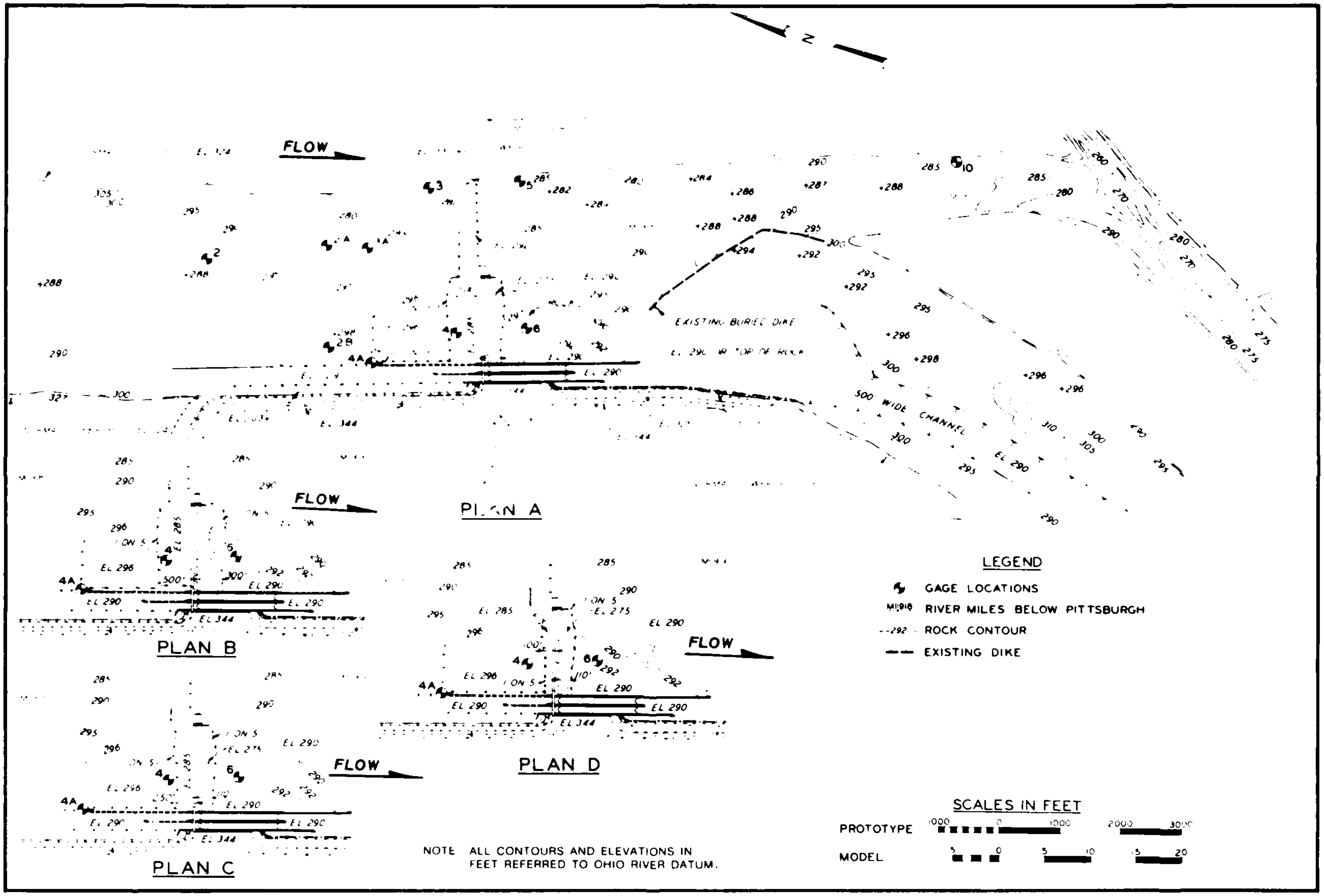


Figure 11. Spillway excavation Plans A, B, C, and D; 11-gate spillway excavation plans

the riverside of the landside lock with 19 ports each 19 ft high by 20 ft wide with top el 309.0. On the land side of the landside lock there was a 210-ft-long solid guide wall plus an 80-ft end section angled 30 deg landward.

Other modifications of the spillway crest elevation and excavations included the following:

a. Plan D-1. Same as Plan D except for the crest of the gate sill which was raised to el 294.0.

b. Plan D-2. Same as Plan D-1 except that the upstream excavation was deepened to el 290.0 and extended to 2,800 ft upstream of the spillway.

c. Plan D-3. Same as Plan D-2 except that the upstream excavation was deepened to el 285.0.

d. Plan D-4. Same as Plan D-3 except that the crest of the gate sill was lowered back to el 290.0.

Results

49. Results shown in Tables 2-4 indicate little difference in the drop in water-surface elevation across the spillway with the 390,000-cfs flow except with Plans D-1, D-2, and D-3 which were about 0.2 to 0.3 ft greater. The difference between gages 4 and 6 was about 1.6 ft except for the latter plans, which were about 1.8 to 1.9 ft attributed mostly to the higher gate sill. However, the drop in water-surface elevation from the end of the upper guard wall (gage 4-A) past the structure (gage 6) varied from about 2.1 ft with Plan D-4 to 2.9 ft with Plan D-1. Except with the higher sill, there was generally little difference in the water-surface elevations through the dam, particularly with the higher flows. A comparison of the results of Plans A and D with the 929,000-cfs flow indicates little or no differences (Table 4). With the 390,000-cfs flow, water-surface elevations upstream of the end of the upper guard wall were 0.2 to 0.3 ft higher with Plan D than with Plan A, which has to be attributed to the difference in the excavation just upstream of the spillway.

Plan D (Fixed-Bed Test)

Description

50. Based on the results of the spillway crest elevation tests, excavation tests, and relative cost of construction, Plan D was selected for further study. This plan was the same as that shown in Figure 10. The crest of the spillway gate sill was at el 290.0. The configuration of the bed was the same as that indicated by the 1966 prototype survey except for the excavation upstream and downstream of the spillway and the lower approach channel 500 ft wide with bottom el 290.0. The locks and lock walls were the same except that the top of the ports in the upper guard walls were lowered to el 302.0 by the Nashville District.

Results

51. Current directions and velocities obtained with this plan are shown in Plates 22-24. These results indicate that with the 390,000- and 600,000-cfs flows, currents in the upper approach to the locks were reasonably straight and generally parallel to the right bank line. Maximum velocities near the guard walls were about 5.0 to 5.9 fps, but currents moved toward the walls at a smaller angle than with the higher ports in the 17-gate spillway tests. A slow clockwise eddy formed along the right bank and extended into the upper approach of the landside lock with the 390,000-cfs flow.

52. Currents from the riverside of the lower guard wall moved across the lower lock approach channel toward the right bank about 3,000 ft downstream of the end of the guard wall, particularly with the 390,000-cfs flow. A slow clockwise eddy formed in the lower approach downstream of the end of the lower guard wall of the riverside lock. Velocities across the lower approach channel varied from about 3.2 fps with the 390,000-cfs flow to more than 6 fps with the 600,000-cfs flow. However, with the higher flow, the alignment of the currents was more nearly parallel to the alignment of the navigation channel.

53. Velocities of currents approaching and leaving the gated spillway were generally higher along the left side of the spillway, particularly when there was little or no flow over the fixed weir. With no

flow over the fixed weir, a counterclockwise eddy would form downstream extending along the left bank. Observations indicated that with the fixed weir placed 250 ft upstream of the axis of the dam, there was some separation of flow just downstream of the curve toward the left spillway abutment which affected flow through gate bays 10 and 11. This condition could be eliminated by placing the fixed weir not more than 160 ft upstream of the axis of the dam by reducing the length of the tangent between the curve and abutment pier.

54. Currents approaching and leaving the overflow weir with the 929,000-cfs flow were generally straight with a slight tendency to move to the right near the structure. Velocities approaching the weir from upstream varied from about 5.1 to 6.4 fps and were considerably less downstream.

55. No serious navigation difficulties were indicated in the lock approaches with the 390,000- and 600,000-cfs flows. There was a slight tendency for the head of a downbound tow to be moved away from the guard wall of the landside lock by the eddy near the lower end of the wall with the lower flow. Tows approaching and leaving the overflow weir in proper alignment and with adequate power should experience no difficulty in passing over the weir with the 929,000-cfs flow.

Plan D (Movable-Bed Test)

Description

56. Plan D was the same as that described for the fixed-bed test outlined in paragraph 50. The model was operated for four runs with each run consisting of the reproduction of the hydrograph recorded in the prototype for the period Nov 1965 to Oct 1966 (Figure 8). Portions of the dike at the upper end of Cumberland Island were removed as they became exposed during the test to reduce its effect on the development of the navigation channel and backwater on the spillway. The dredged channel in the lower approach to the locks was maintained by dredging at the end of each run.

Results

57. Considerable scouring occurred downstream of the left side

of the spillway and along the left side of the lower lock approach channel downstream of the rock outcrop during the first run. Heavy shoaling occurred to the left and downstream of the scour hole below the left side of the spillway. Shoaling also occurred in the lower lock approach channel below the end of the lower guard wall and on the right edge of the dredged channel downstream to about mile 921.5. During the succeeding runs there was some increase in the size of the scour holes and deposition along the right side of Cumberland Island (Plate 25). Shoaling in the lower approach channel continued to decrease except in the reach just downstream of the end of the lower guard wall. Shoaling in the approach channel farther downstream was confined to the right edge where depths were reduced about 2 to 4 ft.

Plan E (Movable-Bed Test)

Description

58. Conditions for the start of Plan E were the same as those obtained at the end of test of Plan D except that two vane dikes were installed downstream of the fixed weir and shoaling in the lower approach channel was removed to el 290.0. The vane dikes were each 900 ft long with top el 310.0 and located on the left side of the scour hole along the left side of the spillway. The upper end of the first dike was about 850 ft downstream of the axis of the dam and angled 15 deg to the right. The upper end of the second dike was about 1,100 ft downstream of the lower end of the first dike and also angled 15 deg to the right (Plate 26).

Results

59. Results shown in Plate 26 indicate that the vane dikes had very little effect on developments in the lower reach. Shoaling in the lock approach just downstream of the end of the lower guard wall was about the same as that with Plan D and slightly greater in the reach farther downstream below the bend in the channel.

Plan F (Movable-Bed Test)

Description

60. The conditions for the start of Plan F were the same as those obtained at the end of test of Plan E except that the vane dikes downstream of the fixed weir and shoaling in the lower approach channel were removed, and a 400-ft-long wing dike was placed at the end of the lower guard wall angled 15 deg to the left with crest el 310.0.

Results

61. Results of test of Plan F after one reproduction of the hydrograph, shown in Plate 27, indicate that the amount of shoaling downstream of the end of the lower guard wall was about three times greater than that with Plans D and E. There was little or no shoaling in the approach channel downstream of the bend, and depths were somewhat greater than those in the previous tests.

Plan G (Movable-Bed Test)

Description

62. Plan G was started with the channel bed the same as that obtained at the end of test of Plan F except that the shoal downstream of the end of the guard wall was removed. The wing dike at end of the lower guard wall was angled 30 deg to the left and the length was increased to 600 ft with the guard wall end placed at el 306.0 and sloped to el 302.0 at its stream end.

Results

63. Results shown in Plate 28 indicate only a slight decrease in the amount of shoaling in the approach channel just downstream of the end of the lower guard wall. There was little or no shoaling in the dredged approach channel downstream of the bend. Deposition toward the channel to the left of Cumberland Island continued during this and the previous test with a tendency for some shoaling in the channel from the mouth of the Cumberland River past the head of Towhead Island. A channel of adequate depth had developed for the first time in the crossing

from the right side of Towhead Island toward the left bank downstream.

Plan H (Movable-Bed Test)

Description

64. The starting bed condition for Plan H was the same as that obtained at the end of Plan G except for the removal of the shoal downstream of the end of the lower guard wall. The wing dike at the end of the lower guard wall was raised to el 310.0. The existing dike along the left bank upstream of Towhead Island was raised to el 305.0, and a 650-ft spur dike was added upstream, also at top el 305.0.

Results

65. Results of test of Plan H, after one reproduction of the annual hydrograph, are shown in Plate 29. These results show a considerable increase in the shoaling in the approach channel downstream of the end of the lower guard wall. Considerable shoaling also occurred in the approach channel downstream. Shoaling in the lower channel occurred along both sides with an indication for the channel to meander. The shoal in the channel between the lower end of Cumberland Island and the left bank opposite the new dike remained and was somewhat higher than that in Plan G. A shoal area had also formed in the entrance to the channel between the lower end of Cumberland Island and Towhead Island. The channel in the crossing toward the left bank downstream of Towhead Island had increased in depth.

Plan I (Movable-Bed Test)

Description

66. Conditions for Plan I were the same as those obtained at the end of tests of Plan H except for the following:

a. The shoal in the approach channel downstream of the locks and the shoal in the entrance to the channel between the lower end of Cumberland Island and Towhead Island were removed.

b. A 900-ft wing dike was added along the lower guard wall about 800 ft upstream of the lower end with top el 305.0. This dike was angled 30 deg to the left, parallel to the wing dike at the end of the wall.

c. Four spur dikes were added along the right bank opposite Cumberland Island, as shown in Plate 30. The top elevations of the dikes were 317, 317, 315, and 313 from upstream to downstream. The ends of the dikes were placed 150 ft from the right edge of the limits of the dredged approach channel, and the dikes were approximately normal to the bank line.

Results

67. Results of test of Plan I shown in Plate 30 indicate considerably less shoaling in the approach channel just downstream of the end of the lower guard wall than with Plan H. Most of the shoaling occurred to the left of the approach channel downstream of the end of the lower wing dike. Except for some shoaling of about 1 to 2 ft along the right edge, a channel was maintained along, and a short distance downstream of, the right bank dikes. Downstream of the dikes, shoaling occurred along the left side, leaving a narrow channel of irregular alignment. The shoal area along the left side of Cumberland Island at mile 921.7 had increased somewhat in size and elevation. The shoal in the entrance to the channel between the lower end of Cumberland Island and Towhead Island reappeared but was considerably less than that obtained in the previous test. An adequate channel was maintained downstream past Towhead Island.

Plan J (Movable-Bed Test)

Description

68. Conditions for Plan J were the same as those obtained at the end of tests of Plan I except for the following:

a. Shoals in the lower approach channel and in the entrance to the channel between the lower end of Cumberland Island and Towhead Island were removed to el 290.0.

b. The two wing dikes along the lower guard wall were removed and replaced with one 600-ft-long wing dike at the end of the wall angled 30 deg to the left with top at el 320.0.

c. Two additional spur dikes were added along the right bank downstream of the dikes in Plan I with crest elevations of 311.0 and 309.0 from upstream to downstream.

Results

69. Results shown in Plate 31 indicate a considerable increase in the shoaling in the lower approach downstream of the end of the lower guard wall. There was an increase in width and depth of the channel in the reach downstream. The shoal area in the entrance to the channel between the lower end of Cumberland Island and Towhead Island reappeared.

Plan K (Movable-Bed Test)

Description

70. Conditions for Plan K were the same as those obtained at the end of test of Plan J except for the following:

a. Shoals in the lower lock approach and in the entrance to the channel between the lower end of Cumberland Island and Towhead Island were removed to el 290.0.

b. The wing dike at the end of the lower guard wall was lowered to el 310.0; and a 400-ft extension downstream, parallel to the alignment of the guard wall, was added to the end of the wing dike with top el 305.0.

Results

71. Results shown in Plate 32 indicate an increase in the amount of shoaling in the lower approach downstream of the end of the lower guard wall. The heaviest shoaling occurred downstream of the wing dike extension, but sediment moved over the top of the wing dike during high flows, causing shoaling across the approach channel to the right bank. There was also some slight shoaling (about 1 to 2 ft) along the right edge of the channel opposite the right bank dikes and a slight encroachment of the sandbar along the left edge of the channel opposite the right bank dike farthest downstream. There was also some increase in the size of the shoal area in the entrance to the channel between the lower end of Cumberland Island and Towhead Island, leaving only a narrow channel of project depth.

Plan L (Movable-Bed Test)

Description

72. Conditions for Plan L were the same as those obtained at the end of the test of Plan K, except for the following:

a. Deposition in the lower approach channel and in the entrance to the channel between the lower end of Cumberland Island and Towhead Island was removed to el 290.0.

b. The wing dike at the end of the lower guard wall was shortened to 450 ft and its top placed at el 315.0. The length of the extension at the end of the wing dike was increased to 550 ft and its crest placed at el 310.0.

Results

73. Results shown in Plate 33 indicate continued heavy shoaling in the lower approach downstream of the end of the lower guard wall. As with Plan K, most of the shoaling occurred along the left side of the channel downstream of the wing dike. The channel downstream of the bend had increased in width and depth. Shoaling in the entrance to the channel between the lower end of Cumberland Island and Towhead Island reappeared and was about 1 to 3 ft above the dredged elevation.

Plan M (Movable-Bed Test)

Description

74. Conditions for the test of Plan M were the same as those obtained at the end of test of Plan L except for the following:

a. Shoals in the approach channel and in the channel between the lower end of Cumberland Island and Towhead Island were removed.

b. The wing dike at the end of the lower guard wall was replaced with an 800-ft-long dike angled 30 deg to the left of the alignment of the guard wall. A second wing dike was added starting 750 ft upstream of the end of the lower guard wall. The dike was 1,200 ft long and angled 30 deg to the left of the lock wall. Both wing dikes were at el 310.0.

The test of this plan consisted of three reproductions of the

Nov 1965-Oct 1966 hydrograph. After the bed was surveyed at the end of each run, the channel in the lower lock approach and in the channel between the lower end of Cumberland Island and Towhead Island was dredged to 500-ft width and bottom elevation of 290.0, as required.

Results

75. Results shown in Plate 34 indicate considerable shoaling downstream of the end of the lower wing dike at the end of the third hydrograph. Most of this shoaling is an accumulation outside the channel prism during the three runs except for the shoaling in the 500-ft-wide channel along the right bank, which was dredged at the ends of runs 1 and 2. By the end of the third run, a channel about 300 ft wide was maintained along the right bank in the lower approach except for isolated depths of 1 to 2 ft above the dredged elevation. Shoaling about 2 to 3 ft above project depth continued in the channel between Cumberland and Towhead Islands. The channel along the ends of the right bank dikes and downstream continued to increase in width and depth.

Plan N (Movable-Bed Test)

Description

76. Conditions for Plan N were the same as those obtained at the end of test of Plan M except for the dredging of a 500-ft channel in the lower lock approach and in the channel between Cumberland and Towhead Islands and extension of the wing dike at the end of the lower guard wall to 1,000 ft.

Results

77. Results shown in Plate 35 indicate some increase in the shoaling in the lower lock approach channel immediately downstream of the guard wall compared with the results of test of Plan M. As with most of the other plans, the lower end of the shoal downstream of the end of the lower wing dike tended to move toward the right bank across the approach channel near the bend in the bank line. The deep channel to the left of the shoal moved to the right along the ends of the upper five dikes, causing some scour on the end of the first and fifth dikes.

There was little change in the shoaling between Cumberland and Towhead Islands although a 300-ft-wide channel was maintained along the lower left side of Cumberland Island.

Plan O (Movable-Bed Test)

Description

78. Conditions for Plan O were the same as those obtained at the end of tests of Plan N except for the dredging in the approach channel and channel between Cumberland and Towhead Islands, and the lower wing dike was reduced in length to 800 ft with the first 200 ft near the guard wall reduced in elevation to 305.0.

Results

79. Results shown in Plate 36 indicate that a scour hole had developed downstream of the lower wing dike and scour material had deposited in the approach channel a short distance downstream of the end of the lower guard wall. Except for this deposition, a channel of about 300-ft width had maintained along the right bank upstream from the bend in the channel. There was some shoaling just outside the left side of the channel opposite the fourth and fifth right bank dikes, but a 500-ft-wide channel was maintained. There was little change in the channel between the lower end of Cumberland Island and Towhead Island.

Discussion of Plans D Through O (Movable-Bed Tests)

80. Plans D through L generally failed to eliminate shoaling in the lower lock approach or in the 500-ft-wide navigation channel downstream extending to mile 922.5. Plans M through O provided reasonably stable navigation channels in the reach; however, Plan M appeared to provide the most dependable navigation channel of these three, since Plan N caused more shoaling in the lower lock approach channel and the shoal in Plan O in the lower lock approach extended farther downstream than in Plan M. It should be noted that additional movable-bed tests discussed in PART VI indicated a need for an additional dike in the lower pool.

Effects of Uneven Gate Operation

Description

81. Tests were conducted to determine the effects of uneven gate operation on shoaling in the lower lock approach. The first test was started with the channel bed as obtained at the end of the test of Plan O except that the channel in the lower lock approach and downstream of the wing dike at the end of the lower guard wall was dredged to el 290.0. The structures were the same as those in Plan O except that the entire length of the lower wing dike was at el 310.0 which made the dike system the same as that in Plan M. The upper pool elevation for controlled flows was maintained by opening the two gates near the fixed weir (Nos. 10 and 11) first and then gradually opening each successive gate toward the lock as discharge increased. The second test was the same as the first test except that gate operation was started near the lock and moved progressively toward the fixed weir. Each gate was opened fully before the next gate was placed in operation.

Results

82. Results of tests with uneven gate operation indicated little difference in the shoaling in the lower lock approach compared with uniform gate operation. Most of the sediment movement through the dam occurs during the high flows when all gates are opened fully and causes most of the shoaling downstream of the wing dikes which gradually moves toward the approach channel. There was little difference between the two methods of operation in the amount of deposition downstream of the wing dikes. The tendency for the lower end of the shoal to move toward the approach channel was somewhat greater with gate operation started near the fixed weir.

PART VI: DEVELOPMENTS DURING CONSTRUCTION

Second-Phase Construction

Description

83. The first-phase construction would include construction of the locks and lock auxiliary walls, and no unusual developments were anticipated. The second-phase construction included the spillway cofferdam, which was scheduled to be in place about 2 years. Tests were conducted to determine the effect of the spillway cofferdam on the dredged lower approach channel and probable maintenance that would be required. The test was started with the second-stage cofferdam and all proposed training structures in place. The model bed was remolded to October 1966 conditions except for the dredged approach channel. The dredged channel and right bank dikes were the same as those in Plan M except that the proposed dredged channel was realigned to the right by moving its lower end about 450 ft toward the right bank at the lower end of Cumberland Island and the dikes were shortened accordingly, as shown in Plate 37. This change in the navigation channel alignment was based on prototype navigation conditions and not on model tests. There was no dredging in the navigation channel between runs 1 and 2.

Results

84. Results shown in Plates 37 and 38 indicate that there would be considerable scouring along the left side of the cofferdam and downstream of the opening between the cofferdam and left bank. Most of the material scoured and some of the material moving through the gap tended to move to the right and extended into the dredged channel. Shoaling in the dredged channel was only about 1 to 2 ft by the end of the first run but increased to about 4 to 5 ft during the second run. The channel downstream of the shoal generally increased in depth with a tendency to move toward the right bank dikes, particularly in the lower reach. A deep scour hole developed on the end of the fifth right bank dike (from upstream) with some decrease in scour on the end of the last dike. During run 2, there was some increase in depths in the channel to the

left of Cumberland Island and downstream of the mouth of the Cumberland River.

Third-Phase Construction

Description

85. The third-phase construction would include the removal of the spillway cofferdam and construction of cells in the fixed weir to el 306.0. Accordingly, conditions for this test were the same as those obtained at the end of the second-phase cofferdam test except for the following:

- a. The cofferdam was removed and all spillway gates were fully open.
- b. The portion of the fixed weir that was within the second-phase cofferdam was in place to final top el 326.0.
- c. The remainder of the fixed weir was in place to the top of the cells at el 306.0.
- d. The navigation channel was redredged.

Results

86. Results shown in Plate 39 indicate that most of the deposition that had occurred downstream of the second-phase cofferdam had been removed with some scouring along the ends of the two wing dikes along the lower lock guard wall. Some of the material scoured was deposited downstream of the wing dikes and along the left side of the lock approach channel, leaving only a narrow channel along the right bank and opposite the ends of the upper right bank dikes. There was some increase in the depth of the scour hole at the end of the fifth dike and some scour on the end of the third dike.

87. Scouring occurred downstream of the fixed weir extending along its entire length but did not appear to be excessive. There was little change in the channel to the left of Cumberland Island except for some increase in depth of the channel from about mile 919.7 to the lower end of the island. A shoal area also developed in the channel opposite the left bank dikes (mile 921.8).

Fourth-Phase Construction

Description

88. The fourth-phase construction would involve completion of the fixed weir to el 326.0. Tests were started with the completed structure and the channel bed in the condition as that obtained at the end of the test with the third-phase construction. The upper pool was maintained by operation of the spillway gates as required for controlled riverflows. Several runs were made, and an L-head dike with crest at el 317.0 was placed upstream of the six right bank dikes before the start of the fourth run to reduce the attack and scour on the upper dikes. The lower approach channel was redredged to el 290.0, as required before the start of each run.

Results

89. Results of tests with the completed structure are shown in Plates 40-43. These results indicate considerable scour downstream of spillway gates 10 and 11 (adjacent to the fixed weir) and immediately downstream of the fixed weir. The depth of the scour hole reached an elevation of about 200.0 some 3,000 ft downstream of the dam. Most of the material scoured was moved downstream and to the left, causing deposition near the head and along the right side of Cumberland Island. Some of the material moved to the right forming a shoal downstream of the wing dikes and along the left side of the approach channel. As deposition increased along the left side of the scour hole and along the head and right side of Cumberland Island, flow from the spillway was concentrated toward the right bank dikes increasing depth in the approach channel and scour on the ends of the dikes. Most of the shoaling in the lower lock approach channel occurred within a mile of the end of the lower lock guard wall along the left side of the channel. There was a tendency for some shoaling in the left side of the channel near the lower end of Cumberland Island downstream of the right bank dikes. Some of the sediment along the right side of Cumberland Island moved across the channel to the right during high flows, causing some deposition on the sandbar along the right bank. Adequate depths were maintained in

the channel from the mouth of the Cumberland River to the lower end of Cumberland Island except for the tendency for a center bar to form opposite the dikes along the left bank upstream of Towhead Island. The addition of the L-head dike improved conditions near the structure but did not materially affect the current attack on the dikes downstream.

90. Scouring occurred downstream of the fixed weir, particularly near its junction with the gated spillway where depths reached el 208.0. There was shoaling along the left side of Cumberland Island near and upstream of the head of the island, but a channel was maintained along the left bank.

Special Tests

91. After completion of the model study for the development of the essential features of the project, a number of special tests were conducted to determine conditions that would exist during various phases of construction and to provide information that would assist the contractor in planning the various sequences of construction and the effects that could be expected. Some of these tests included the following:

- a. Velocity measurements in the channel between the second-stage cofferdam and the left bank for flows ranging from 170,000 to 1,030,000 cfs.
- b. Velocity measurements along the left bank below the mouth of the Cumberland River to determine its susceptibility to scour as affected by construction of the project.
- c. Tests to determine the stability of cofferdam cells that would be part of the overflow weir before the weir was completed.
- d. Tests to determine velocities that would affect construc- of the fixed weir with each increment of closure.
- e. Tests to determine navigation conditions in the upper lock approach during construction of the fixed weir.

Results of these tests were furnished the district office concerned as they became available. Since these data would be applicable only to the Smithland project during construction, they are not included in this report.

PART VII: DISCUSSION OF RESULTS AND CONCLUSIONS

Limitations of Model Results

92. The model was designed and operated to obtain some general indications of effects of the proposed plan and various modifications on water-surface elevations, current directions, and velocities, and effects of currents on the movement of tows, scour, and shoaling tendencies. Most of the current directions and velocities were obtained with the bed of the model reproducing the conditions as indicated by the available prototype survey made in 1966, and the results would not reflect the effects of changes in the bed configuration that would occur with the structures in place. Also, it should be considered in the evaluation of the results that some changes in the alignment of currents and velocities are not necessarily changes produced by modifications in plan since several floats introduced at the same point may follow different paths and move at slightly different velocities because of pulsating currents and eddies. The current directions and most of the velocities shown in the plates were taken with floats submerged to a depth of a loaded barge (prototype) and are generally indicative of the currents that would affect the behavior of tows.

93. For most of the tests, a portion of the model was converted to a movable bed to indicate changes in the configuration of the channel bed, shoaling tendencies, and need for remedial structures. The accuracy with which a movable-bed model reproduces prototype conditions depends on verification of the model and information on the erodibility of the material forming the bed of the prototype channel. It should be considered that the conventional type of verification was not possible in this model because of the limited data available. However, adjustment of the model was considered adequate to indicate, at least qualitatively, the general tendencies that can be expected in the prototype with the conditions imposed on the model. It should also be considered that conditions in the prototype would be affected to some extent by the existence of bed rock and some erosion-resistant material.

Bedrock, particularly in the vicinity of the spillway, was simulated in the model based on information made available which was changed somewhat during the course of the study based on the results of additional and more detailed probes in the prototype. It should also be considered that the structures produced a drastic change in the movement of sediment and distribution of flow through the reach. The movable-bed tests were generally limited in duration and might not indicate fully the ultimate conditions that might develop over a long period of time and with flows that might be substantially different from those reproduced.

94. Because of the small model scale, it was difficult to reproduce accurately the hydraulic characteristics of the prototype structures or to measure water-surface elevations within an accuracy of about ± 0.1 ft prototype.

Summary of Results and Conclusions

95. The following results and conclusions were developed during the investigation.

- a. Satisfactory navigation conditions in the lock approaches could be developed with the 17- or 11-gate spillway and with a 600- and a 1,200-ft lock or with two 1,200-ft locks.
- b. Navigation conditions in the upper lock approach would be better with the dike along the right side of the approach channel moved at least 50 ft landward of that proposed in the original design and extended upstream at least 700 ft (total length 1,055 ft). The landward movement of the dike would provide tows additional maneuver area landward of the guard wall, and the upstream extension of the dike would cause flow from the right overbank and Dog Creek to enter the approach channel far enough upstream to reduce its effect on downbound tows moving along the bank line.
- c. Ports will be required in the upper guard wall to reduce or eliminate the crosscurrents near the end of the wall. With ports in the upper guard wall but not in the upper wall between the two locks, downbound tows (particularly large tows) would experience considerable difficulty in approaching a guide wall on the landside of the landside lock because of currents moving toward the ports in the guard wall of the riverside lock away from the guide wall.

d. With two 1,200-ft locks, conditions would be considerably better for downbound tows using the landside lock with a guard wall on the riverside of that lock. Ports would be required in the guard wall of the landside lock (the middle wall in the upper approach), and the guard wall on the riverside lock would have to be extended at least 750 ft upstream of the end of the guard wall on the riverside of the landward lock.

e. Tests on the 17-gate spillway had the top of the ports 10 ft below the normal upper pool elevation while the 11-gate spillway had the top of the ports 22 ft below the normal upper pool. Test results indicated that the deeper ports on the 11-gate spillway produced less of a draft toward the riverside guard wall when approaching the landside lock than with the higher ports on the 17-gate spillway.

f. Satisfactory navigation conditions could be developed in the lower lock approach with a guard wall (riverside) of the riverside lock and with a guide wall (landside) of the landside lock with two 1,200-ft adjacent locks or with a common center-wall extension, as in Plan C (17-gate spillway). The center wall would tend to be more efficient since tows can enter or leave either lock without interfering with tows using the other lock. However, upbound tows using the riverside lock would use more power in approaching the wall because of currents in the approach and along the wall.

g. Because of the expansion in channel width downstream of the end of the riverside lock wall, there is a general tendency for shoaling in the lower lock approaches. The tendency for shoaling in the lower approach to the Smithland Lock is aggravated by the elevation of the rock downstream of the gated spillway, causing some of the sediment to move toward the approach channel.

h. Normally, shoaling in the lower lock approach can be eliminated or reduced considerably with a wing dike located near the end of the riverside lock wall. However, because of the movement of sediment from along the left side of the rock outcrop toward the lock approach channel, the typical wing dike that has been successful in other similar structures was not effective with the Smithland Locks. Use of two wing dikes as developed in this study was successful in reducing the amount and frequency of dredging.

i. Uneven gate operation starting by opening the gates from the locks toward the fixed-crest weir or from the fixed-crest weir toward the lock would have very little effect on deposition in the lower lock approach channel, since

most of the sediment moving through the spillway occurs during high flows when all gates are open. Conditions were slightly better with gate operation started near the lock since flow through those gates would cause any material deposited on the rock downstream of the open gates to move toward the left downstream of the closed gates.

j. Closure of the channel between Cumberland Island and the left bank near the head of the island would tend to cause shoaling in the entrance to the channel between Cumberland and Towhead Islands.

k. Developments in the channel downstream of the structure will be affected by the elevation and shape of bedrock downstream of the gated spillway. Deep scour will occur downstream of the gates near the fixed weir with flow from the scour moving mostly toward the right bank some distance downstream with deposition along the right side of Cumberland Island. Dikes will be required along the right bank to prevent the channel from meandering between the right bank and Cumberland Island.

l. Conditions in the reach downstream of the dam could be adversely affected by the existing dike extending upstream of the head of Cumberland Island. Portions of this dike should be removed as it becomes exposed.

m. Except for shoaling in the reach just downstream of the locks, the lower approach channel will tend to become deeper and remain adjacent to the ends of the right bank dikes. Some of the sediment deposited along the right side of Cumberland Island will be moved across the approach channel toward the bar along the right bank downstream of the dikes and could cause shoaling problems during some flows.

n. Because of the reduced Ohio River flow in the channel to the left of Cumberland Island, width of the channel between Cumberland and Towhead Islands, and flow diverted through the channel between Towhead Island and the left bank, some shoaling can be expected in that channel with the 11-gate spillway.

o. Flow through the two spillway gate bays near the fixed weir can be improved considerably by placing a curved guide wall upstream of the left abutment pier or by locating the fixed weir about 160 ft upstream of the axis of the dam and shaping its right end to form a curve to tie in with the abutment pier.

p. Cofferdams proposed during construction of the project would form an obstruction to flow in the river, particularly those required for the construction of the gated

spillway. Considerable scour can be expected on the upstream corner and riverward face of the gated spillway cofferdam depending on the amount of flow and erodibility of the bed material. A deflector placed on the upstream end of the riverward cofferdam face, as developed during model study, would move the scour away from the main cofferdam and tend to prevent tows from hitting the structure.

q. Excessive scour will occur downstream of the fixed weir and spillway gates 10 and 11. This scour will require some protection immediately downstream of the fixed weir. The scour downstream of gates 10 and 11 will not cause any problem due to the rock outcrop upstream of the scour.

Table 1

Second-Stage Cofferdam Tests

Plan I, 11-Gate Spillway

Gage No.		Water-Surface Elevation, ft NGVD Discharge 615,000 cfs	Discharge 760,000 cfs	Discharge 855,000 cfs
1		334.9	339.0	341.6
2		334.8	339.0	341.5
3		333.4	337.8	340.5
3-A		333.3	337.7	340.4
3-B		333.4	337.8	340.5
4		334.5	338.7	341.4
5		332.1	336.5	339.3
5-A		332.0	336.4	339.2
5-B		331.8	336.3	339.5
6	Control gage	331.6	336.1	338.8
10		331.9	336.4	338.9

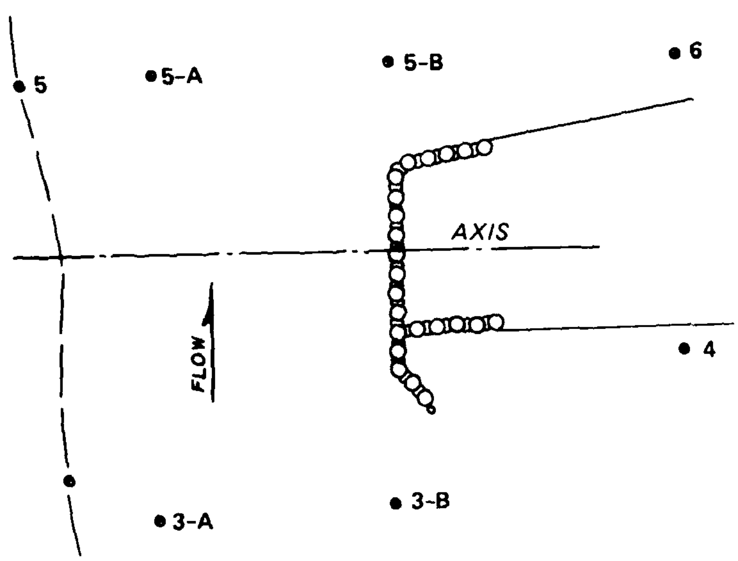


Table 2

Spillway Excavation Tests

390,000-cfs Discharge

Gage No.*	Water-Surface Elevation, ft NGVD			
	Plan A	Plan B	Plan C	Plan D
1	325.6	325.6	325.7	325.8
2	325.5	325.5	325.6	325.8
2-A	325.2	325.3	325.3	325.5
2-B	325.1	325.2	325.2	325.4
3-A	325.2	325.3	325.4	325.5
3	325.2	325.2	325.5	325.6
4-A	324.9	325.0	325.0	325.1
4	324.1	324.1	324.0	324.1
5	322.5	322.6	322.4	322.4
6 Control gage	322.5	322.5	322.5	322.5
10	322.3	322.3	322.3	322.3
	Plan D-1	Plan D-2	Plan D-3	Plan D-4
1	326.2	325.7	325.5	325.2
2	326.2	325.7	325.4	325.1
2-A	325.9	325.4	325.2	324.7
2-B	325.7	325.4	325.2	324.7
3-A	325.9	325.4	325.4	324.7
3	325.9	325.4	325.2	324.9
4-A	325.4	325.3	325.1	324.6
4	324.3	324.4	324.4	324.1
5	322.4	322.3	322.3	322.3
6 Control gage	322.5	322.5	322.5	322.5
10	322.0	322.0	322.0	321.9

* Gage locations shown in Figure 3. Gage 1 located mile at 916.8.

Table 3

Spillway Excavation Tests

427,000-cfs Discharge

Gage No.*	Water-Surface Elevation, ft NGVD Plan A	Plan B	Plan C	Plan D
1	327.3	327.4	327.5	327.6
2	327.2	327.2	327.4	327.5
2-A	327.0	327.0	327.0	327.1
2-B	326.9	327.0	327.0	327.0
3-A	327.0	327.0	327.0	327.1
3	327.0	327.1	327.1	327.2
4-A	326.6	326.7	326.7	326.7
4	325.8	325.7	325.6	325.7
5	324.0	324.0	324.0	324.0
6 Control gage	324.0	324.0	324.0	324.0
10	323.7	323.8	323.8	323.7

* Gage locations shown in Figure 3.

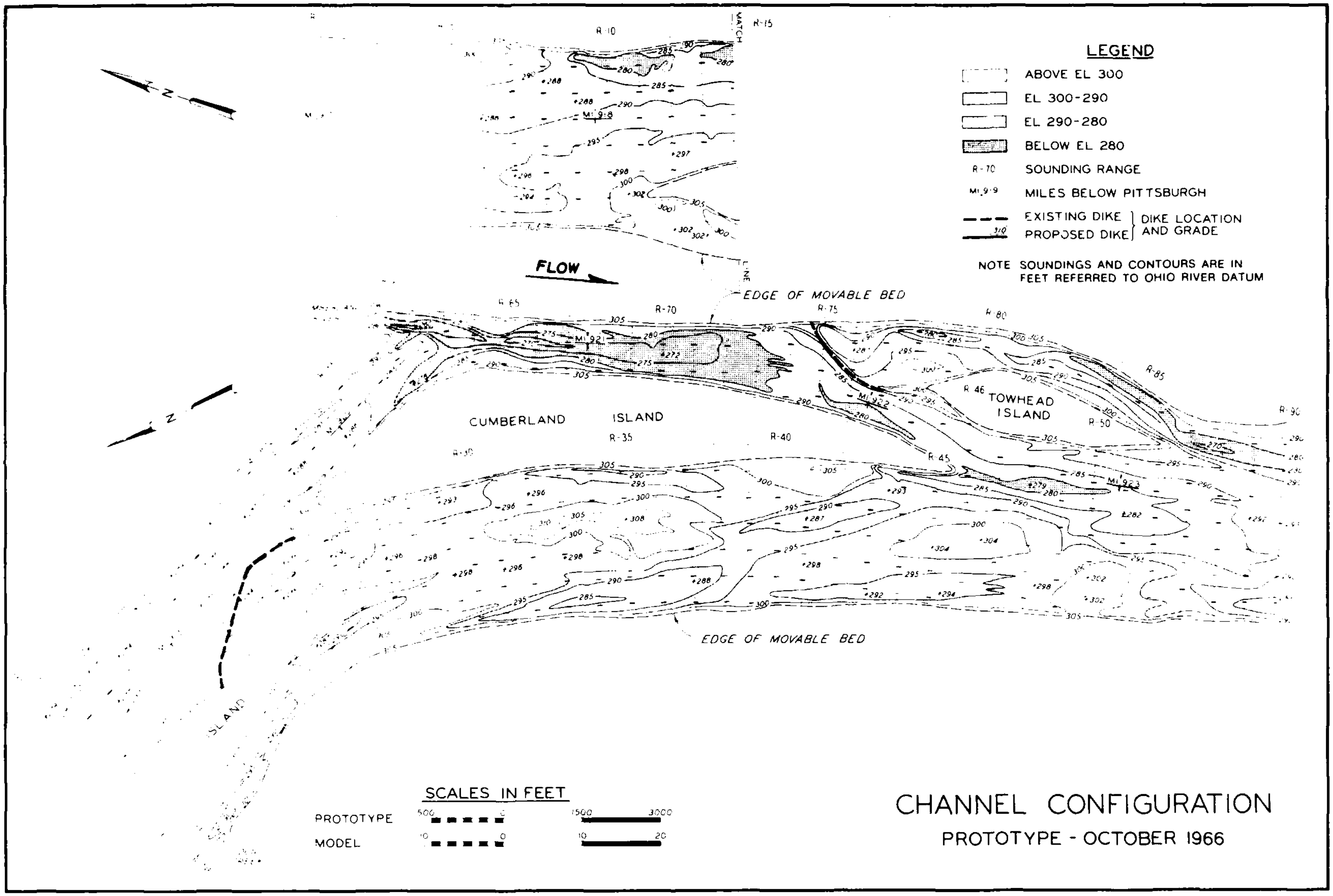
Table 4

Spillway Excavation Tests

929,000-cfs Discharge

Gage No.*	Water-Surface Elevation, ft NGVD Plan A	Plan D
1	343.0	343.3
2	342.8	343.1
2-A	342.8	342.6
2-B	342.8	342.6
3-A	342.7	342.6
3	342.6	342.8
4-A	342.7	342.7
4	342.0	342.1
5	341.5	341.6
6 Control gage	341.5	341.5
10	341.4	341.5

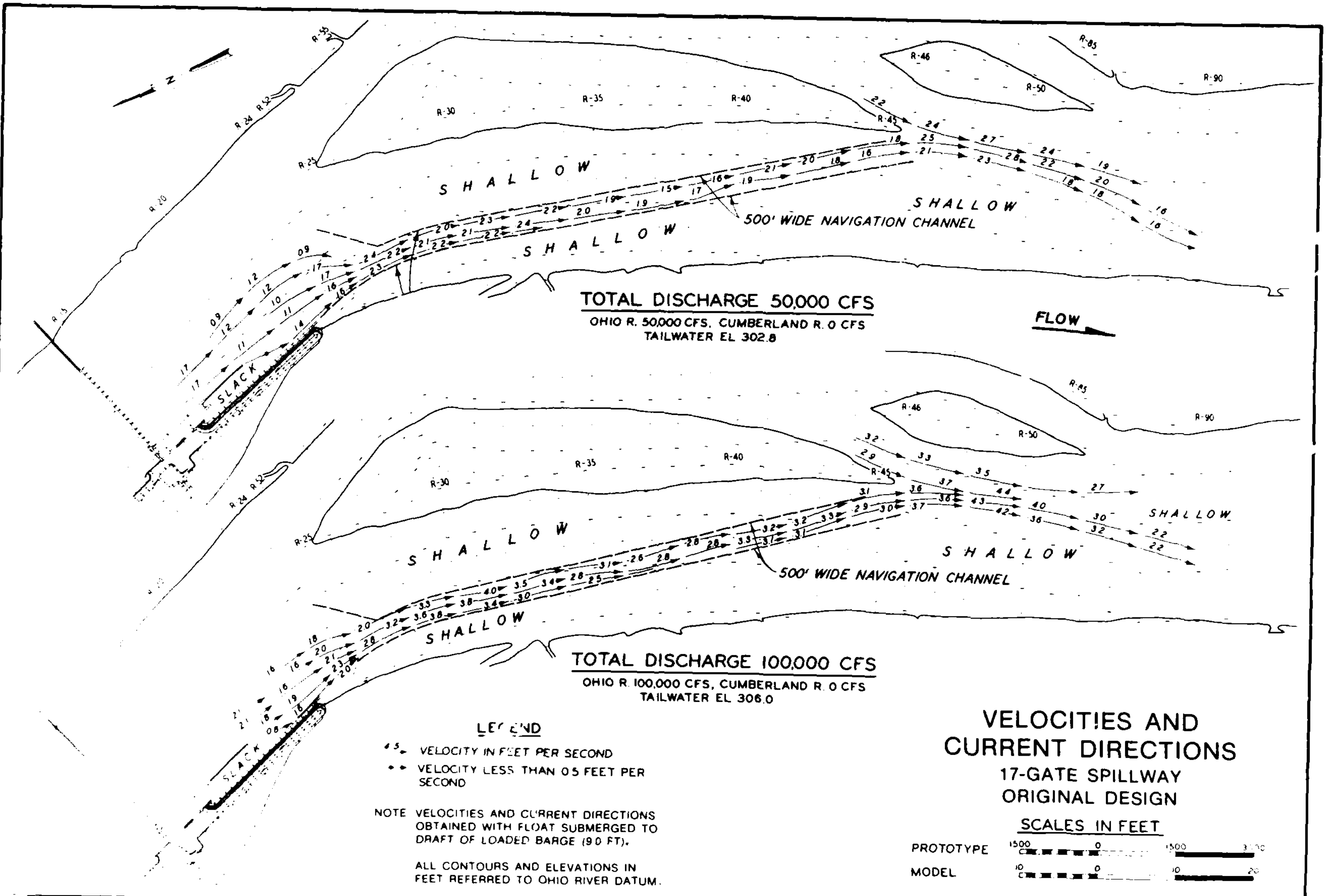
* Gage locations shown in Figure 3.



CHANNEL CONFIGURATION

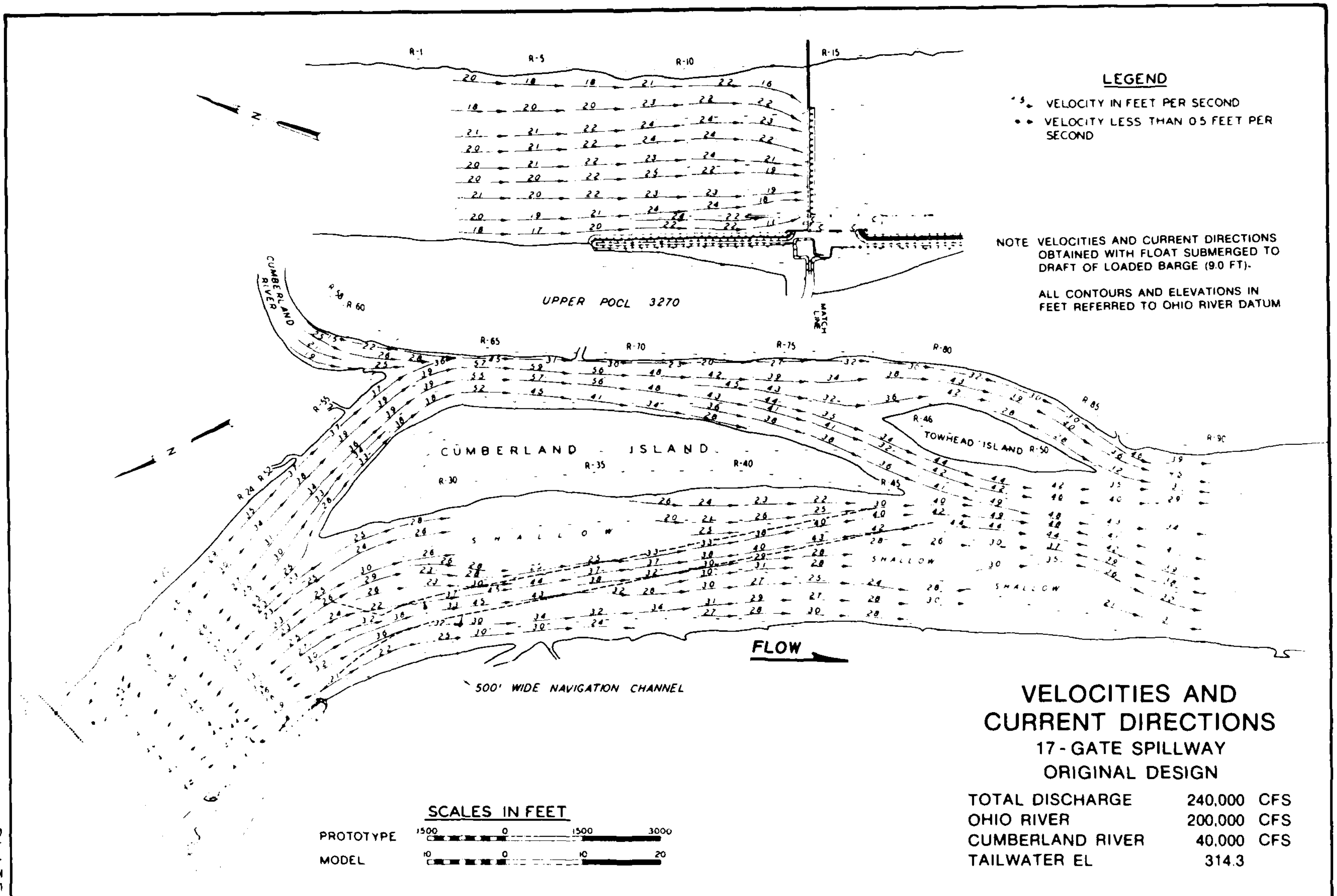
PROTOTYPE - OCTOBER 1966

PLATE 1



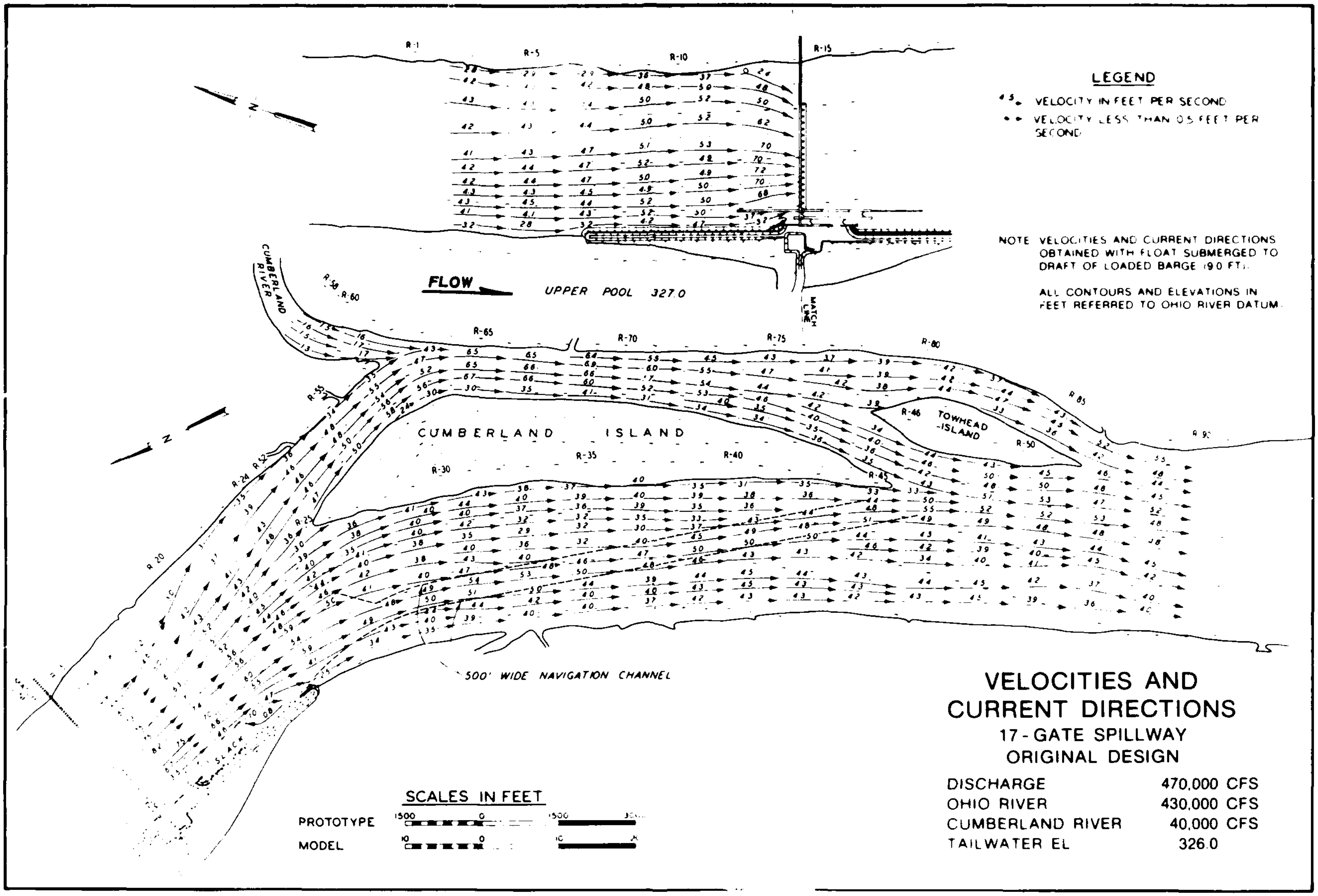
VELOCITIES AND CURRENT DIRECTIONS
17-GATE SPILLWAY
ORIGINAL DESIGN

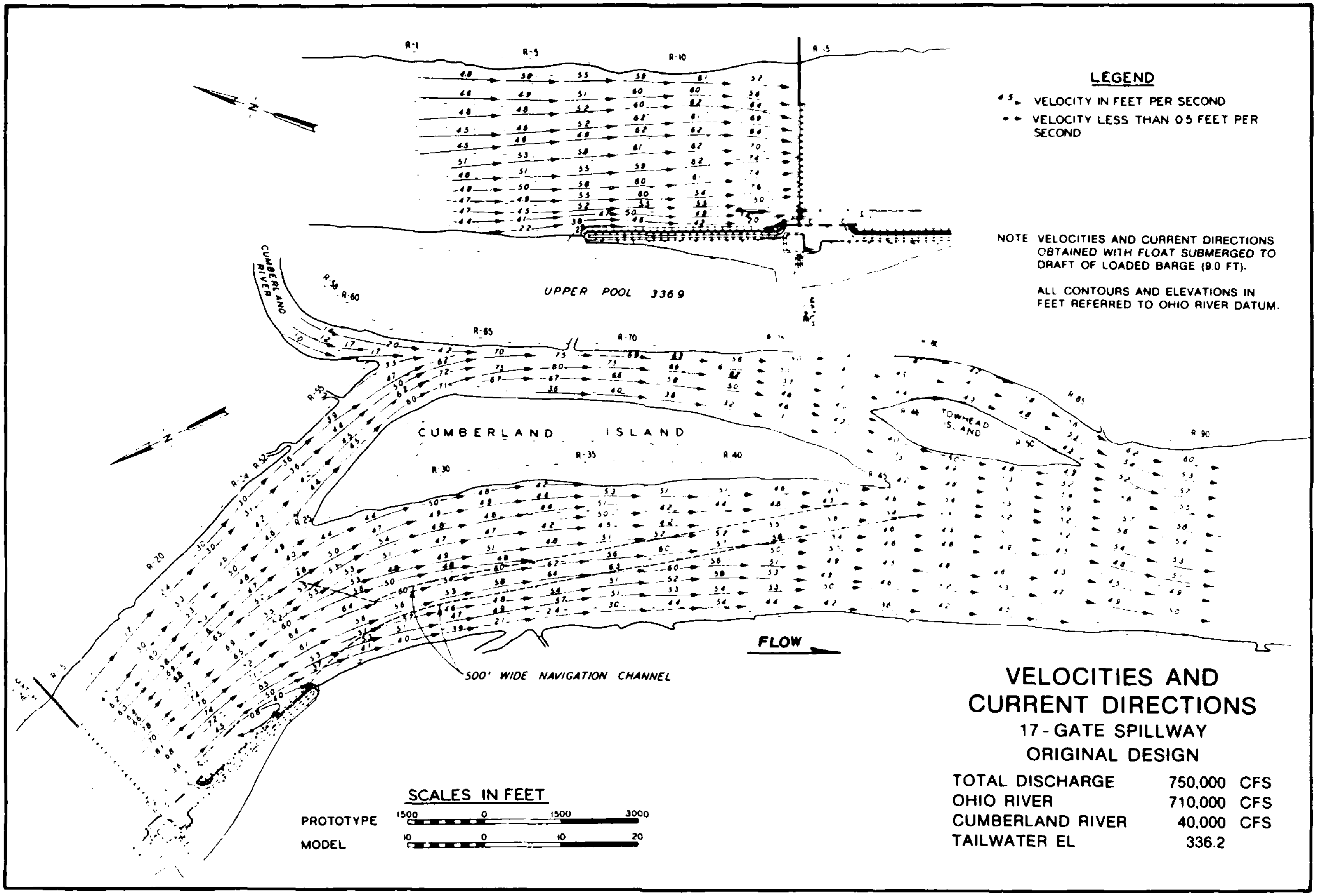
PLATE 2



VELOCITIES AND CURRENT DIRECTIONS
17-GATE SPILLWAY
ORIGINAL DESIGN

TOTAL DISCHARGE	240,000	CFS
OHIO RIVER	200,000	CFS
CUMBERLAND RIVER	40,000	CFS
TAILWATER EL	314.3	


LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.
FLOW
UPPER POOL 327.0
MATCH LINE
CUMBERLAND RIVER
CUMBERLAND ISLAND
TOWHEAD ISLAND
500' WIDE NAVIGATION CHANNEL
SCALES IN FEET
PROTOTYPE
MODEL
VELOCITIES AND CURRENT DIRECTIONS
17-GATE SPILLWAY
ORIGINAL DESIGN
DISCHARGE 470,000 CFS
OHIO RIVER 430,000 CFS
CUMBERLAND RIVER 40,000 CFS
TAILWATER EL 326.0


LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.
UPPER POOL 336.9
CUMBERLAND RIVER
CUMBERLAND ISLAND
TOWHEAD ISLAND
FLOW
500' WIDE NAVIGATION CHANNEL
SCALES IN FEET
PROTOTYPE 1500 0 1500 3000
MODEL 10 0 10 20
VELOCITIES AND CURRENT DIRECTIONS
17-GATE SPILLWAY
ORIGINAL DESIGN
TOTAL DISCHARGE 750,000 CFS
OHIO RIVER 710,000 CFS
CUMBERLAND RIVER 40,000 CFS
TAILWATER EL 336.2

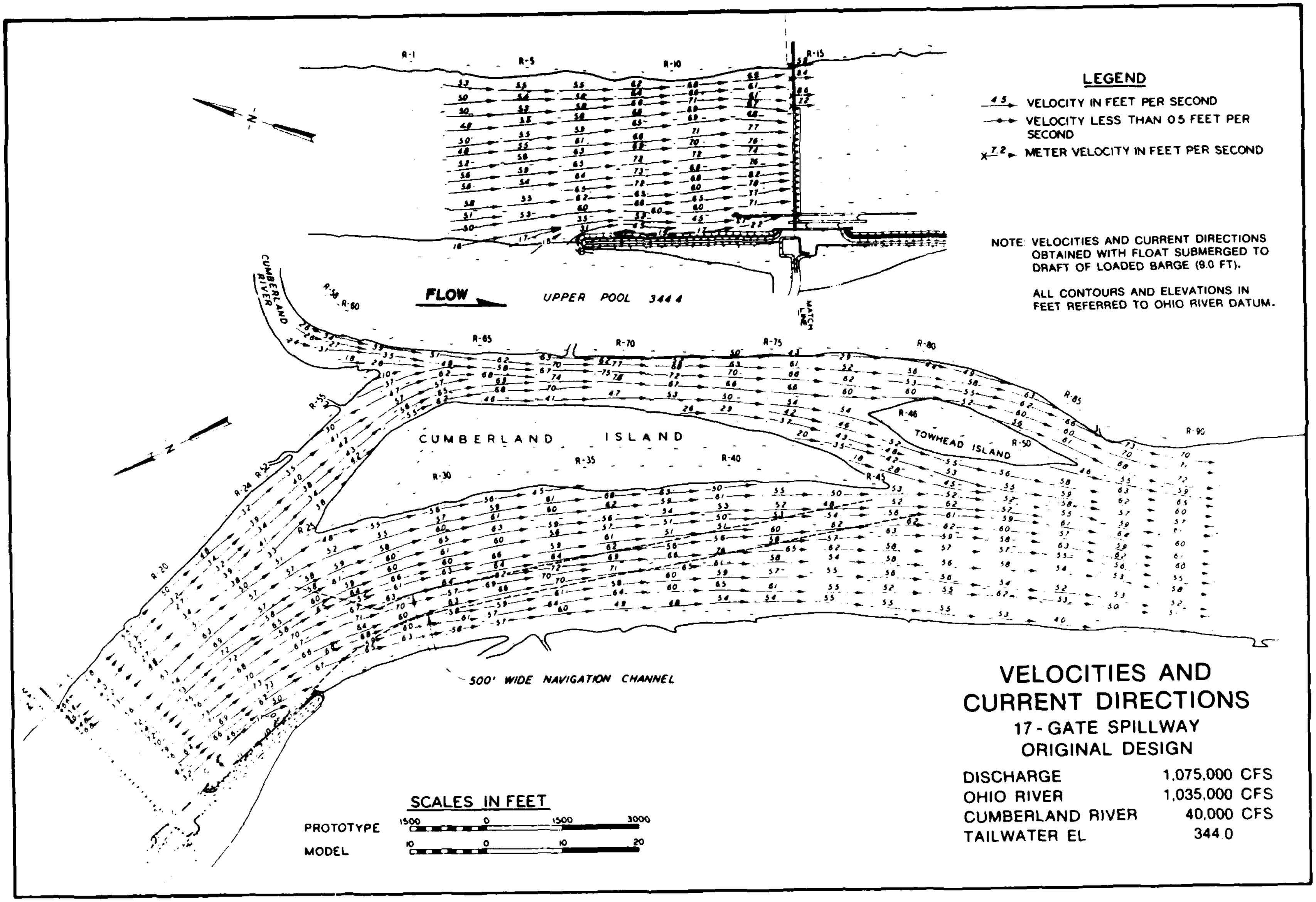
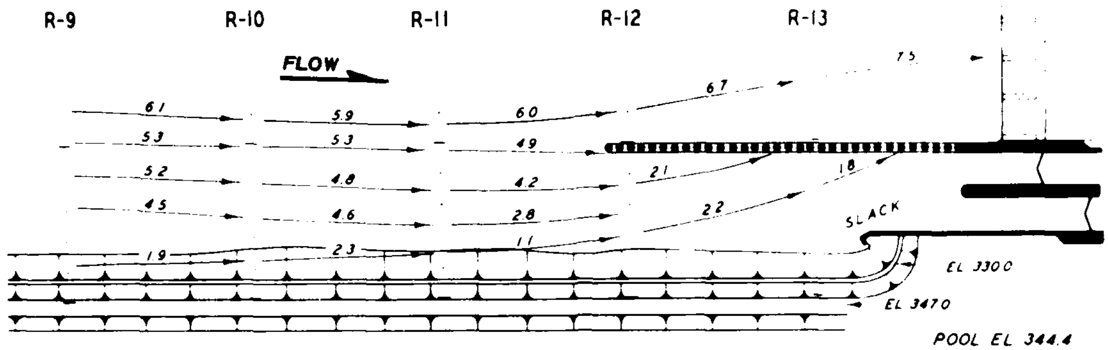
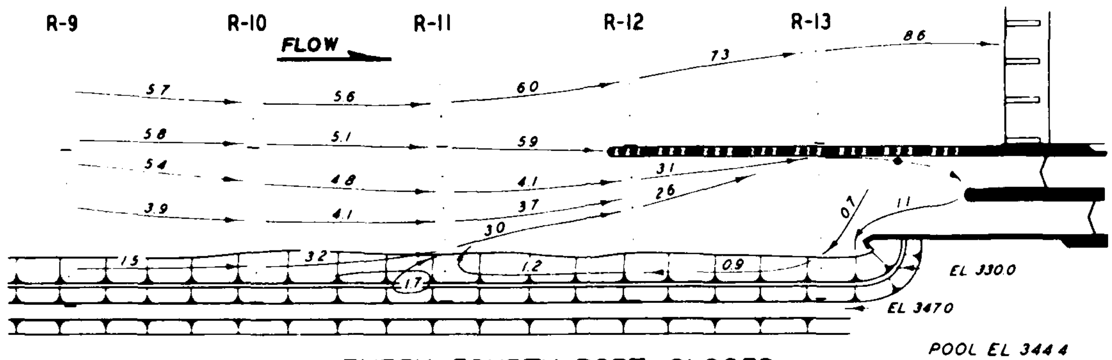

VELOCITIES AND CURRENT DIRECTIONS
17-GATE SPILLWAY
ORIGINAL DESIGN
DISCHARGE 1,075,000 CFS
OHIO RIVER 1,035,000 CFS
CUMBERLAND RIVER 40,000 CFS
TAILWATER EL 344.0
LEGEND
4.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
7.2 METER VELOCITY IN FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.
FLOW
UPPER POOL 344.4
MATCH LINE
CUMBERLAND RIVER
CUMBERLAND ISLAND
TOWHEAD ISLAND
500' WIDE NAVIGATION CHANNEL
SCALES IN FEET
PROTOTYPE 1500 0 1500 3000
MODEL 10 0 10 20
N

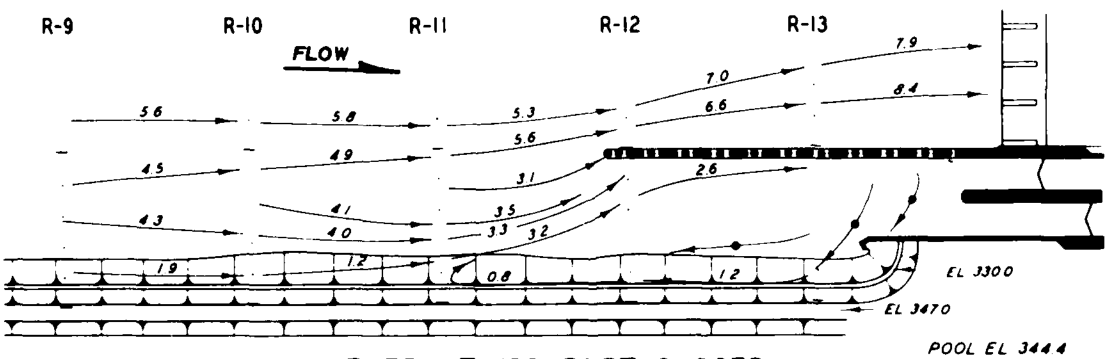
PLATE 6



ALL PORTS OPEN



EVERY FOURTH PORT CLOSED



EVERY THIRD PORT CLOSED

LEGEND

4.5 —→— VELOCITY IN FEET PER SECOND

—●→— VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT)

ALL ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.

PORTS ARE 10' WIDE X 27' HIGH WITH TOP AT EL 317.0.

VELOCITIES AND CURRENT DIRECTIONS

17-GATE SPILLWAY

EFFECTS OF PORT OPENINGS

ORIGINAL DESIGN

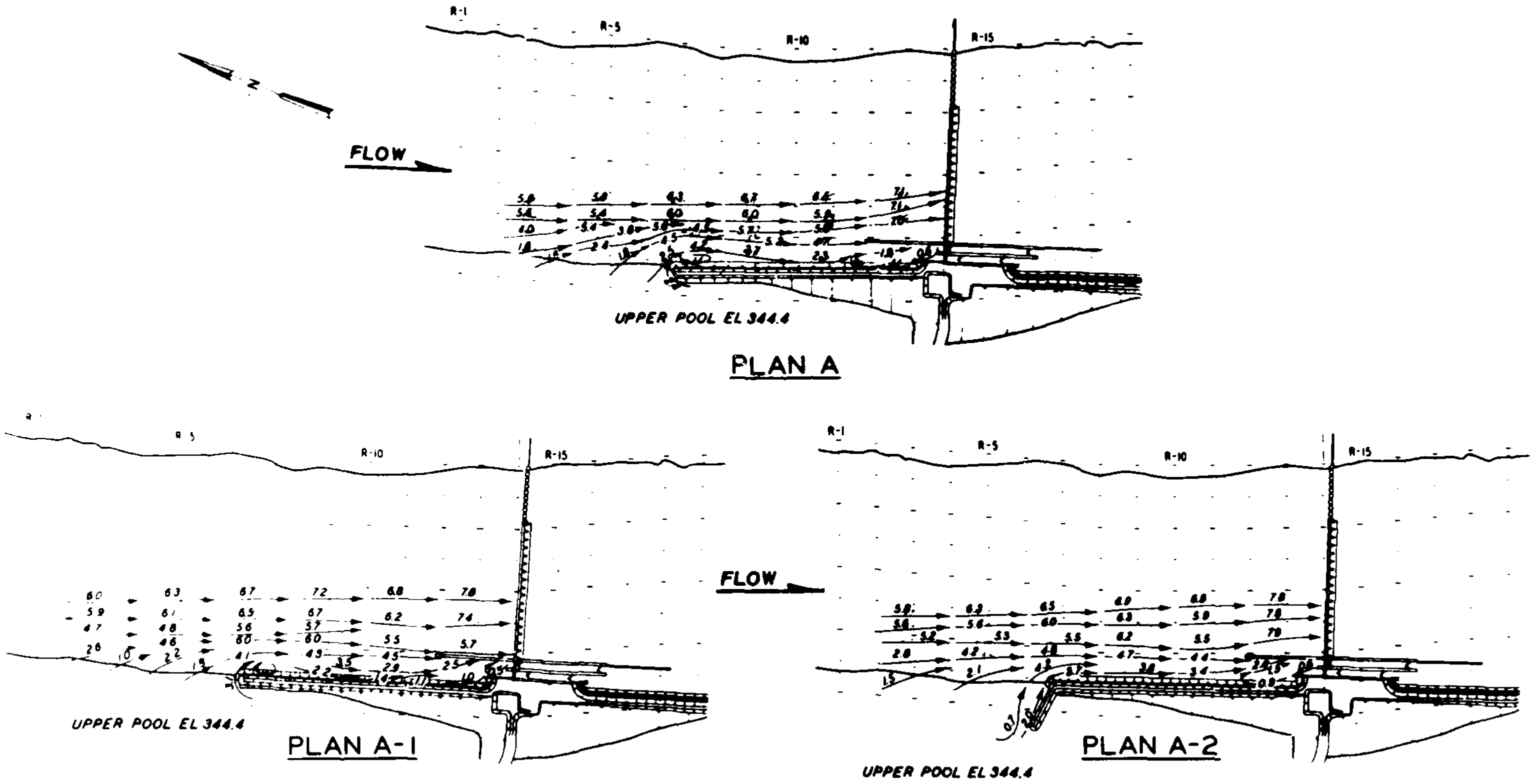
DISCHARGE 1,075,000 CFS

TAILWATER EL 344.0

SCALES IN FEET

PROTOTYPE 300 0 300 600 900

MODEL 2 0 2 4 6



LEGEND

4.5 → VELOCITY IN FEET PER SECOND

← → VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000

MODEL 10 0 10 20

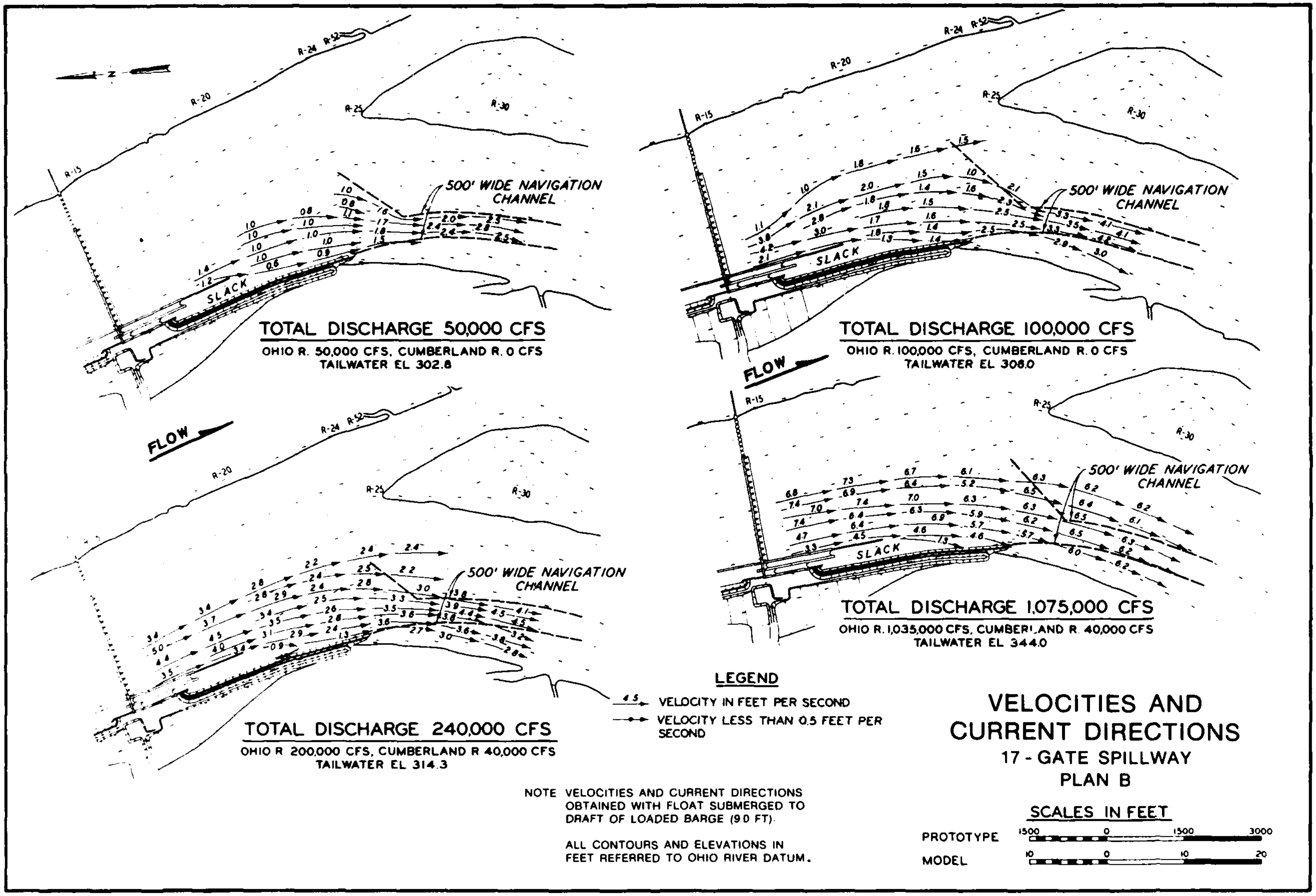
VELOCITIES AND CURRENT DIRECTIONS

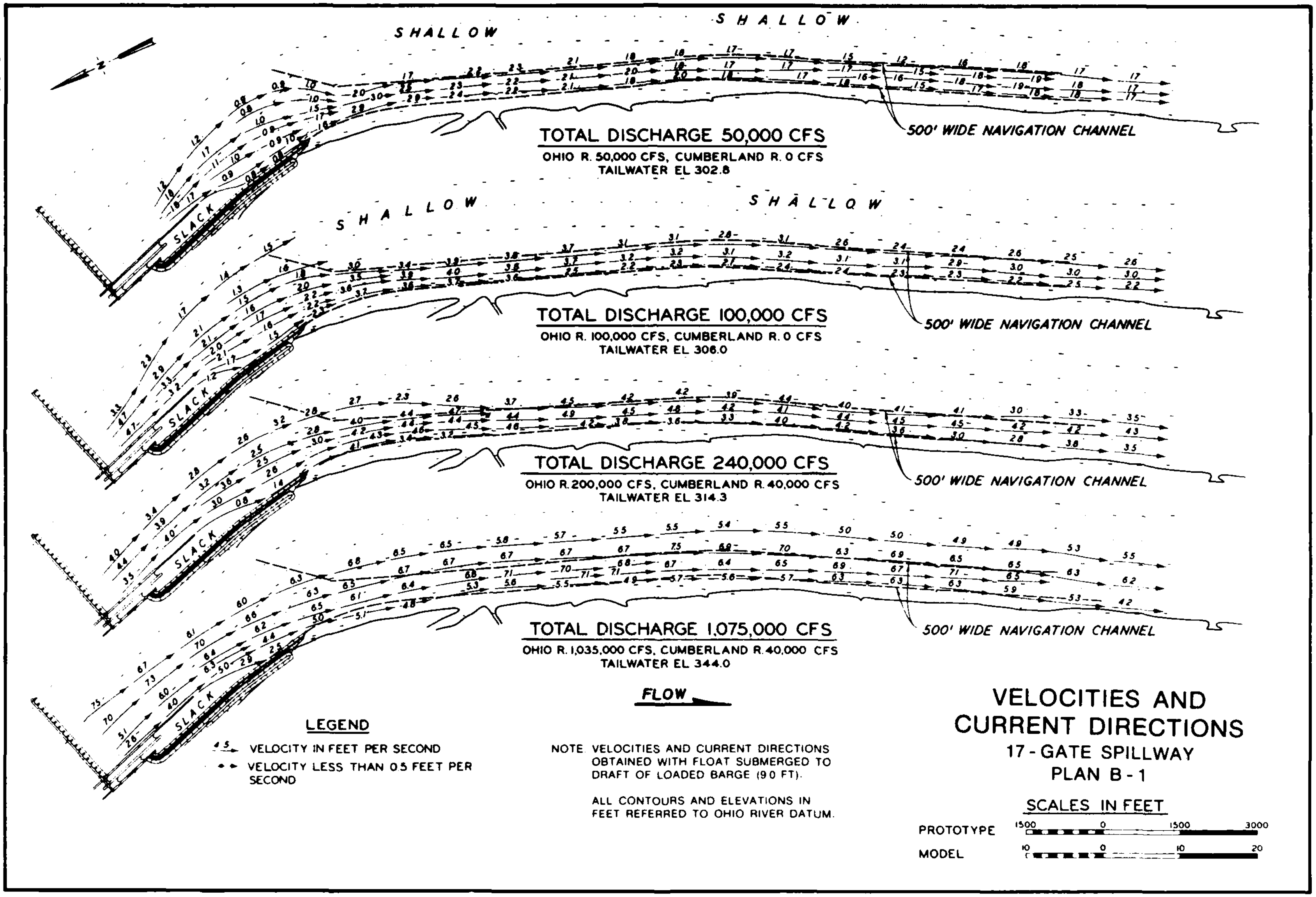
17 - GATE SPILLWAY
PLANS A, A - 1, AND A - 2
TOTAL DISCHARGE 1,075,000 CFS

OHIO R 1,035,000 CFS

CUMBERLAND R 40,000 CFS

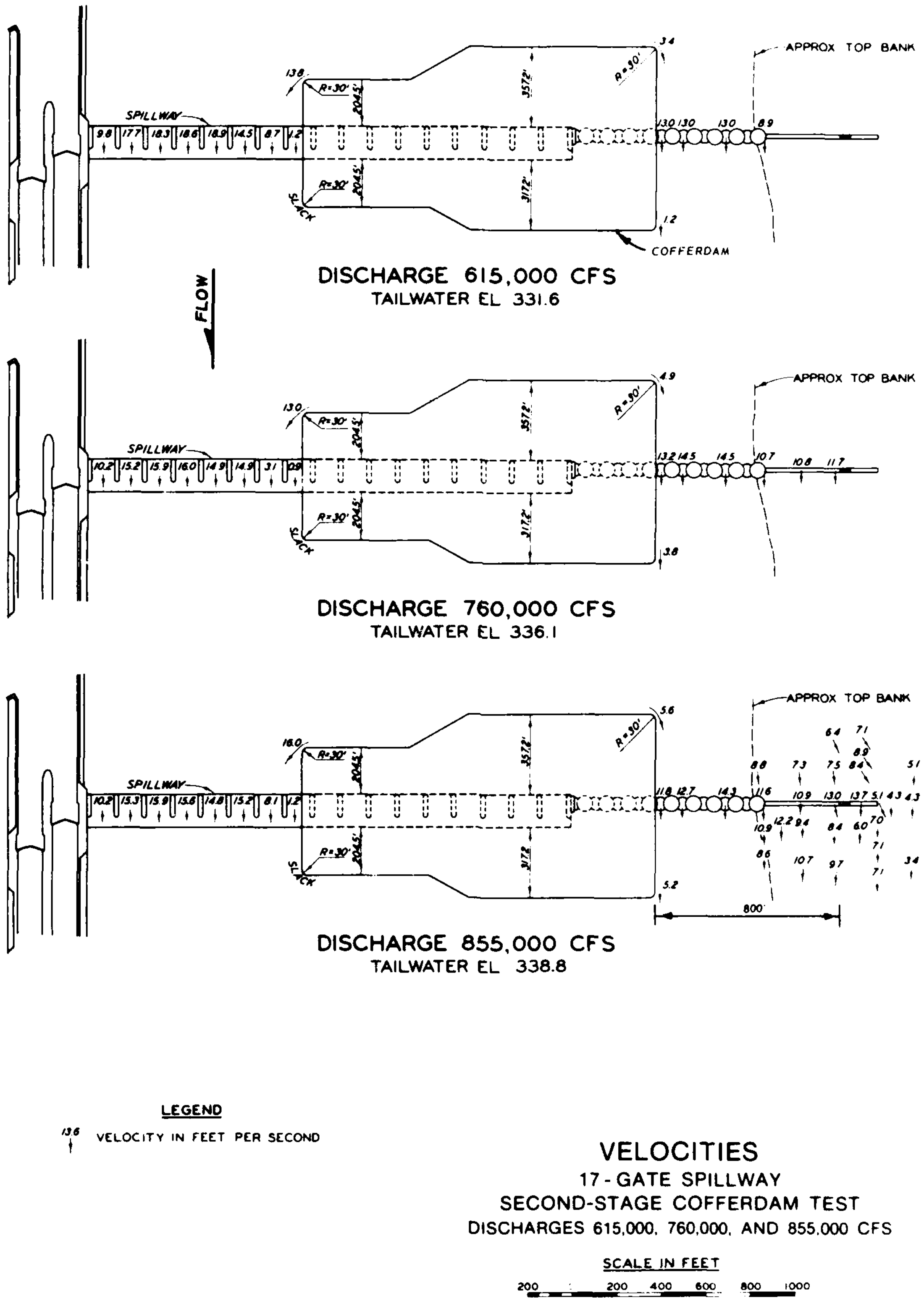
TAILWATER EL 344.0


TOTAL DISCHARGE 50,000 CFS
OHIO R. 50,000 CFS, CUMBERLAND R. 0 CFS
TAILWATER EL 302.8
TOTAL DISCHARGE 100,000 CFS
OHIO R. 100,000 CFS, CUMBERLAND R. 0 CFS
TAILWATER EL 306.0
TOTAL DISCHARGE 240,000 CFS
OHIO R 200,000 CFS, CUMBERLAND R 40,000 CFS
TAILWATER EL 314.3
TOTAL DISCHARGE 1,075,000 CFS
OHIO R. 1,035,000 CFS, CUMBERLAND R. 40,000 CFS
TAILWATER EL 344.0
500' WIDE NAVIGATION CHANNEL
SLACK
FLOW
N
R-15
R-20
R-24
R-25
R-30
R-52
LEGEND
4.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.
VELOCITIES AND CURRENT DIRECTIONS
17 - GATE SPILLWAY
PLAN B
SCALES IN FEET
PROTOTYPE 1500 0 1500 3000
MODEL 10 0 10 20

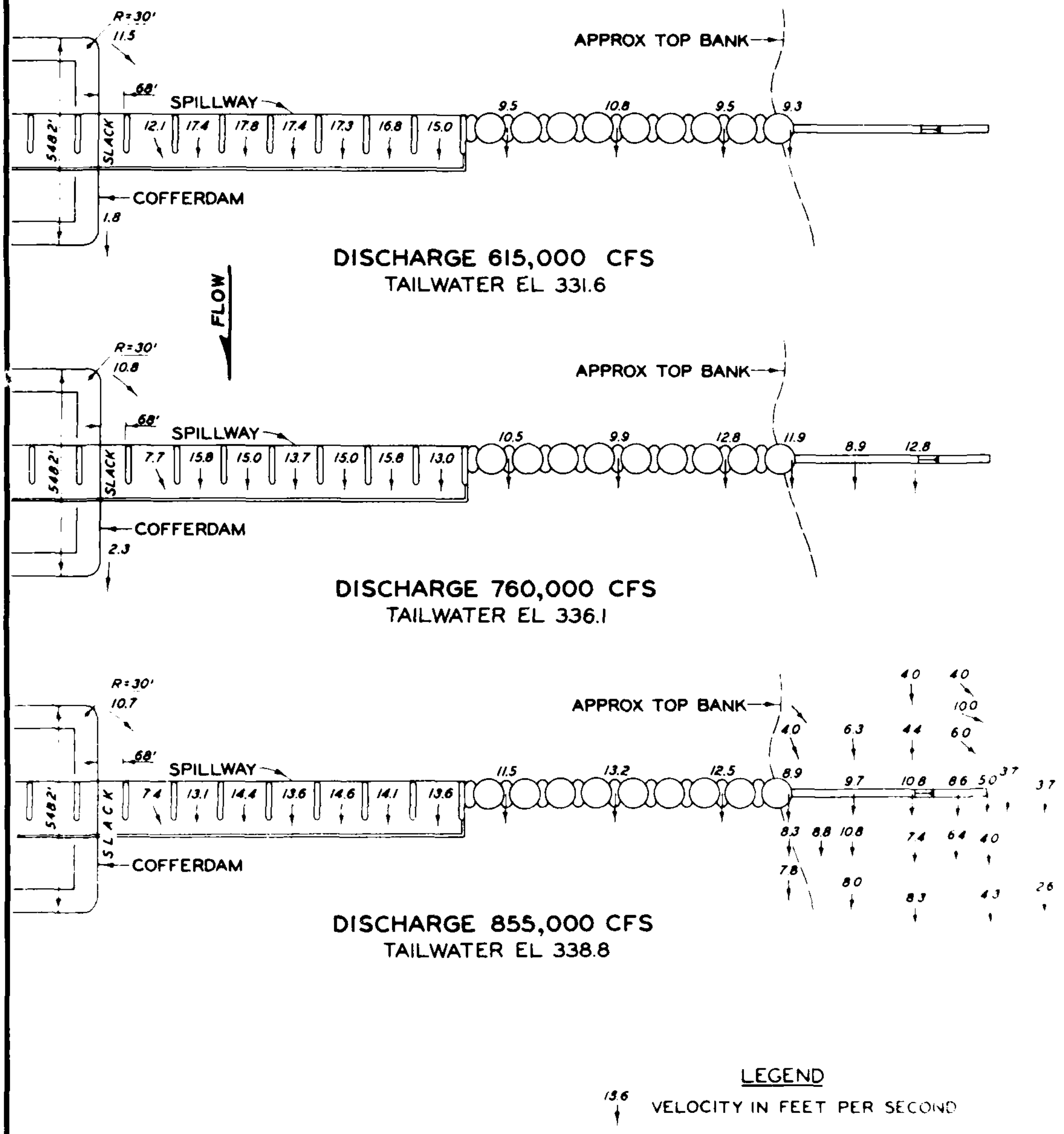


SHALLOW
TOTAL DISCHARGE 50,000 CFS
OHIO R. 50,000 CFS, CUMBERLAND R. 0 CFS
TAILWATER EL 302.8
TOTAL DISCHARGE 100,000 CFS
OHIO R. 100,000 CFS, CUMBERLAND R. 0 CFS
TAILWATER EL 306.0
TOTAL DISCHARGE 240,000 CFS
OHIO R. 200,000 CFS, CUMBERLAND R. 40,000 CFS
TAILWATER EL 314.3
TOTAL DISCHARGE 1,075,000 CFS
OHIO R. 1,035,000 CFS, CUMBERLAND R. 40,000 CFS
TAILWATER EL 344.0
500' WIDE NAVIGATION CHANNEL
SLACK
FLOW
LEGEND
4.5 VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE. VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.
VELOCITIES AND CURRENT DIRECTIONS
17-GATE SPILLWAY
PLAN B-1
SCALES IN FEET
PROTOTYPE 1500 0 1500 3000
MODEL 10 0 10 20

PLATE 10



VELOCITIES
17-GATE SPILLWAY
SECOND-STAGE COFFERDAM TEST
DISCHARGES 615,000, 760,000, AND 855,000 CFS



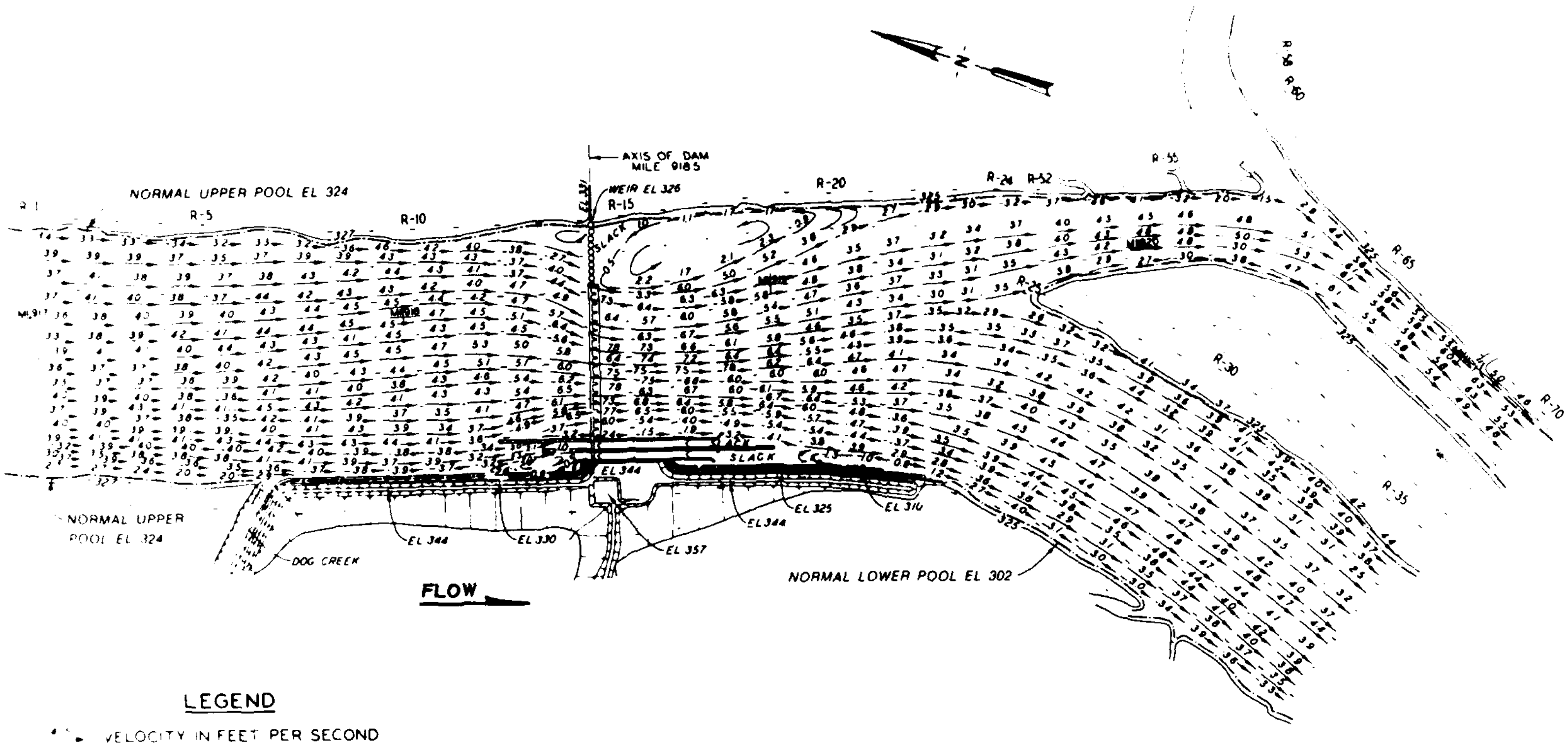
VELOCITIES

17 - GATE SPILLWAY
THIRD-STAGE COFFERDAM TEST
DISCHARGES 615,000, 760,000, AND 855,000 CFS

SCALE IN FEET

200 0 200 400 600

PLATE 12



LEGEND

- VELOCITY IN FEET PER SECOND
- VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000

MODEL 10 0 10 20

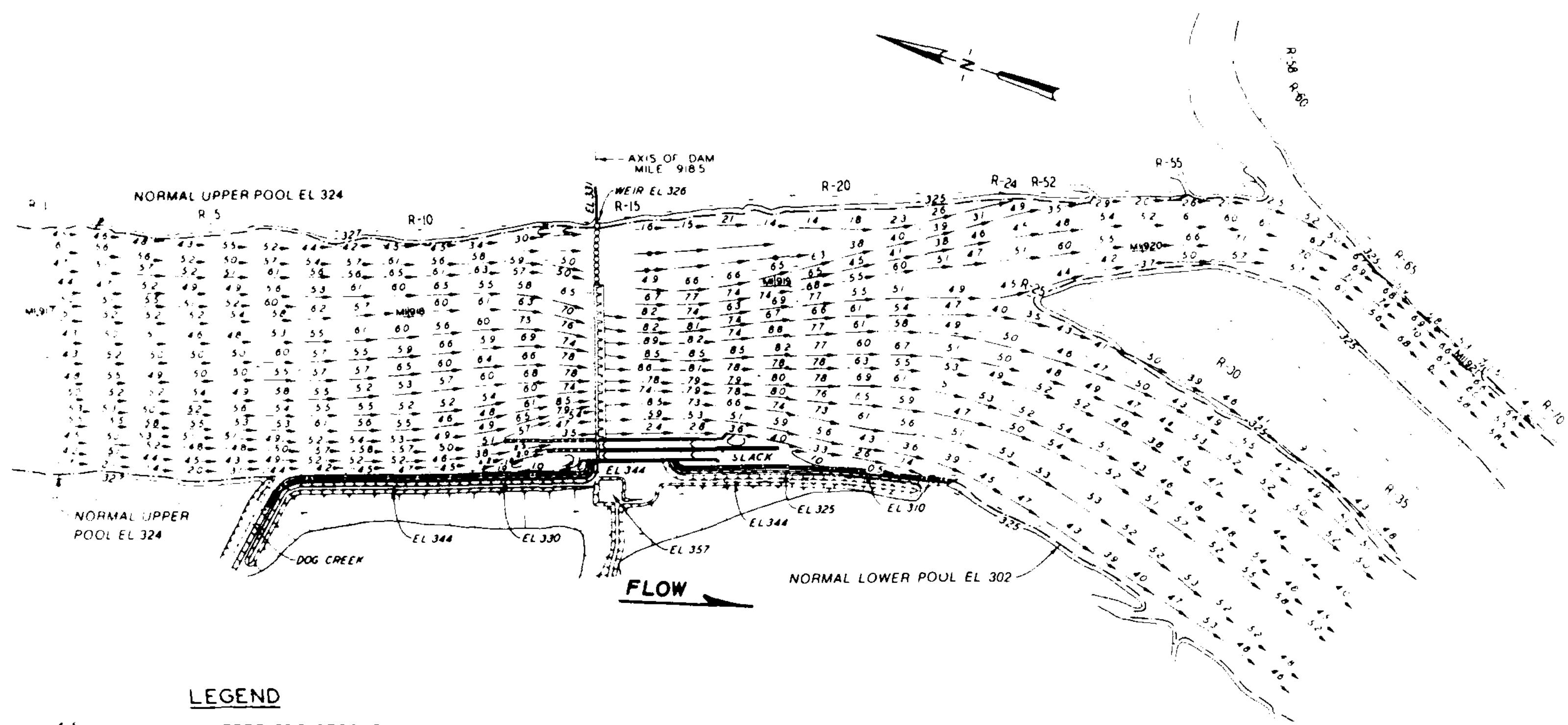
VELOCITIES AND CURRENT DIRECTIONS

17-GATE SPILLWAY

PLAN C

DISCHARGE 405,000 CFS

TAILWATER EL 323.1



LEGEND

VELOCITY IN FEET PER SECOND

VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000

MODEL 10 0 10 20

VELOCITIES AND CURRENT DIRECTIONS

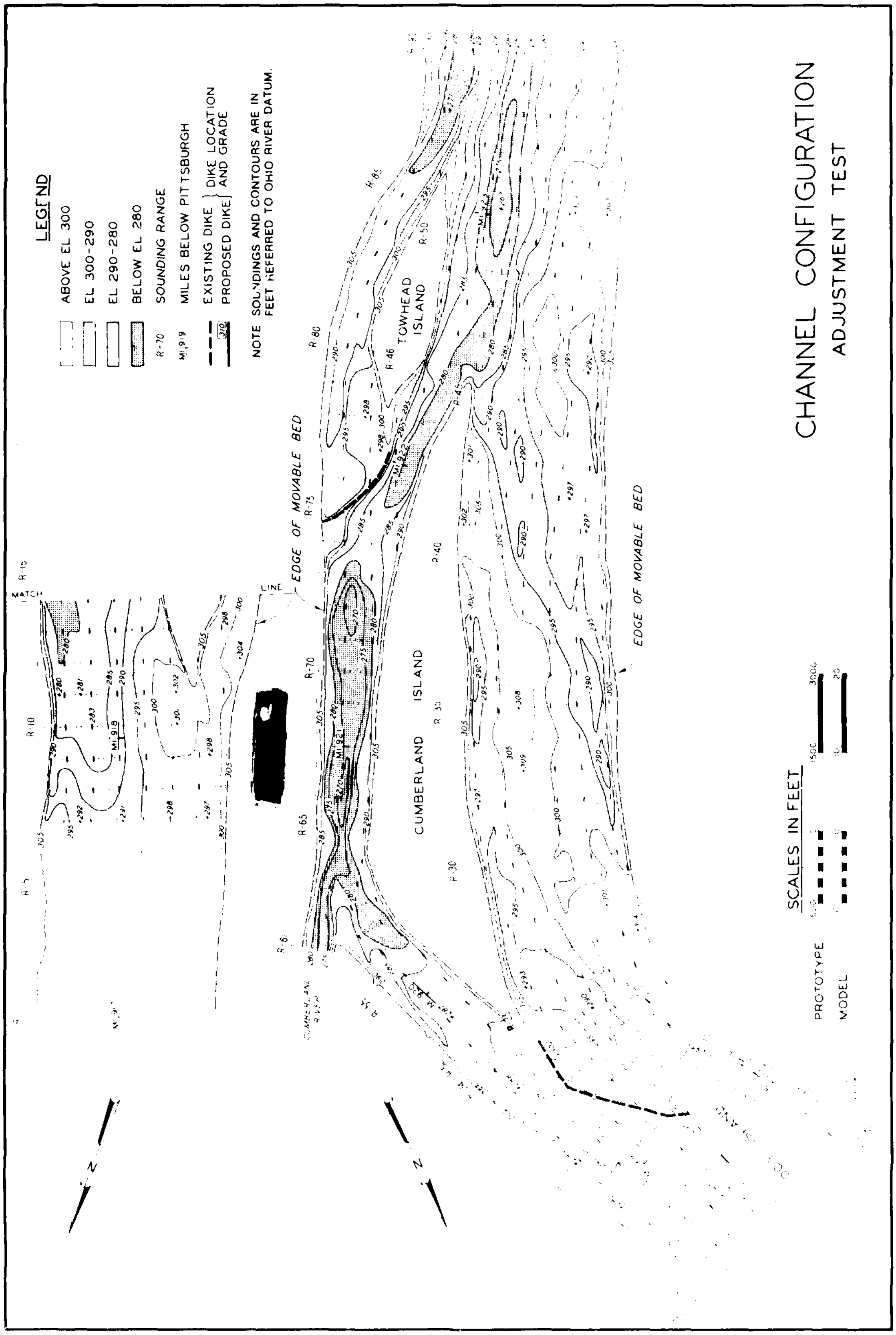
17-GATE SPILLWAY

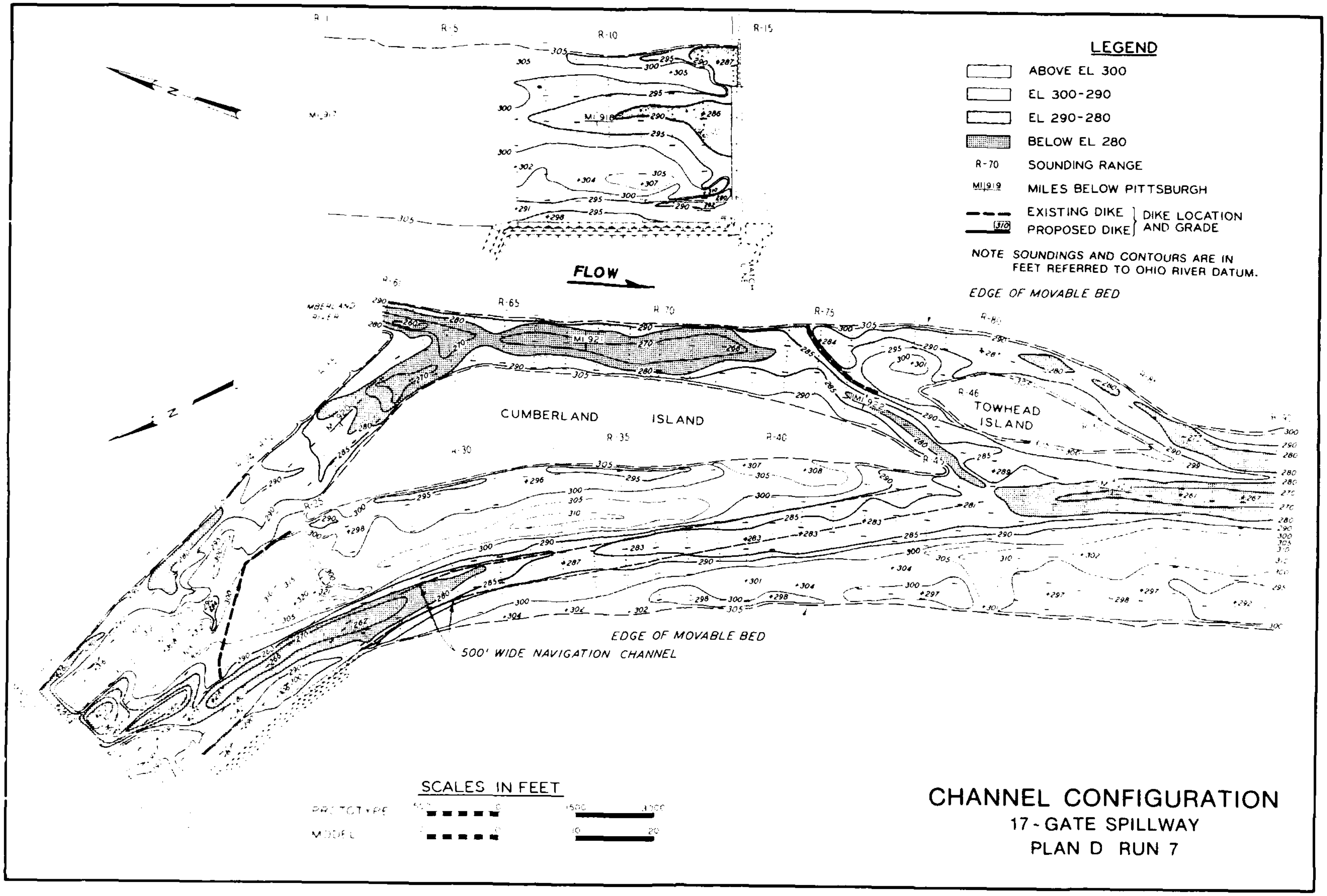
PLAN C

DISCHARGE 600,000 CFS

TAILWATER EL 331.0

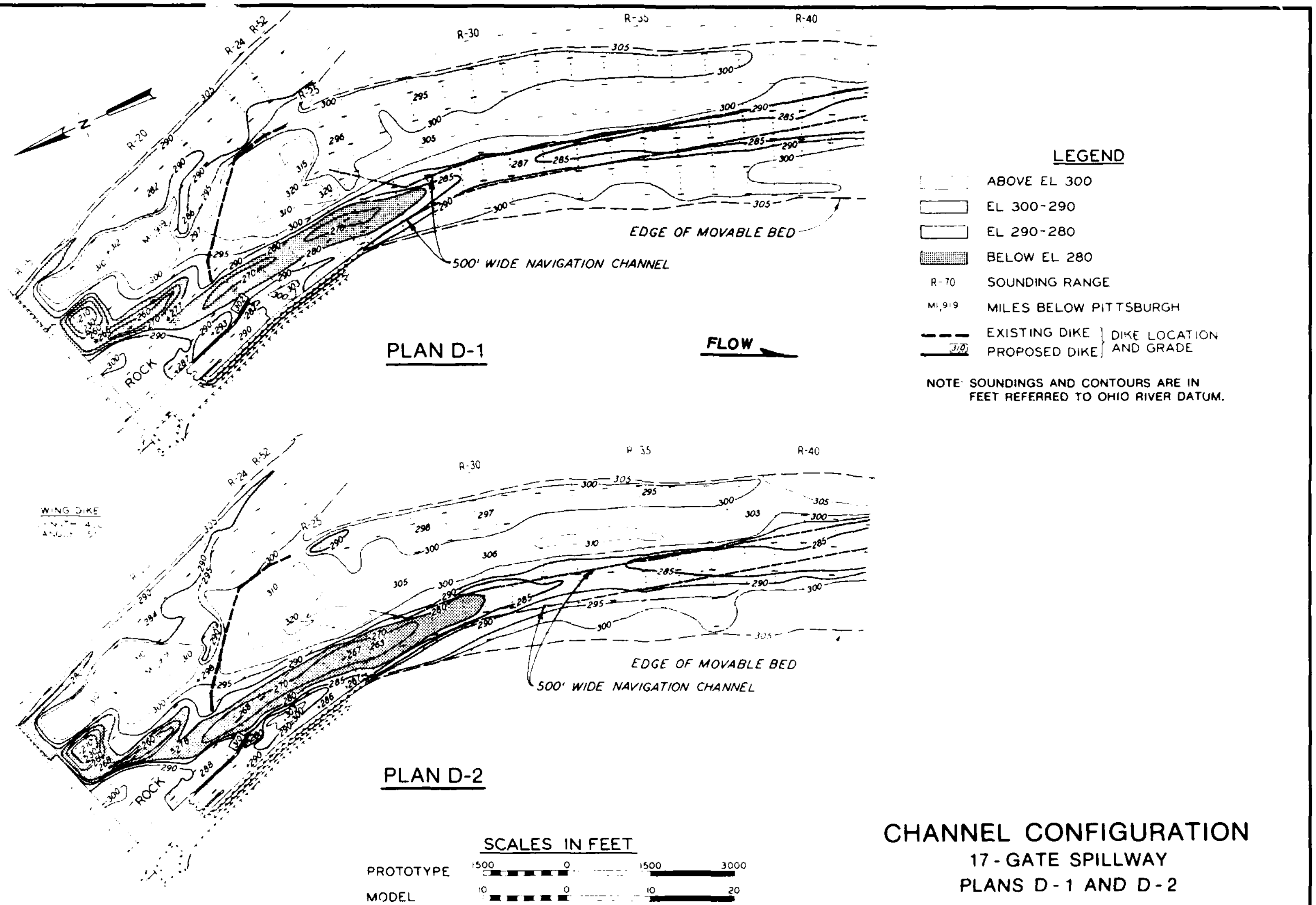
PLATE 14


LEGEND
ABOVE EL 300
EL 300-290
EL 290-280
BELOW EL 280
SOUNDING RANGE
MILES BELOW PITTSBURGH
EXISTING DIKE
PROPOSED DIKE
DIKE LOCATION AND GRADE
NOTE: SOUNDINGS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
EDGE OF MOVABLE BED
MATCH LINE
TOWHEAD ISLAND
CUMBERLAND ISLAND
SCALES IN FEET
PROTOTYPE
MODEL
CHANNEL CONFIGURATION
ADJUSTMENT TEST

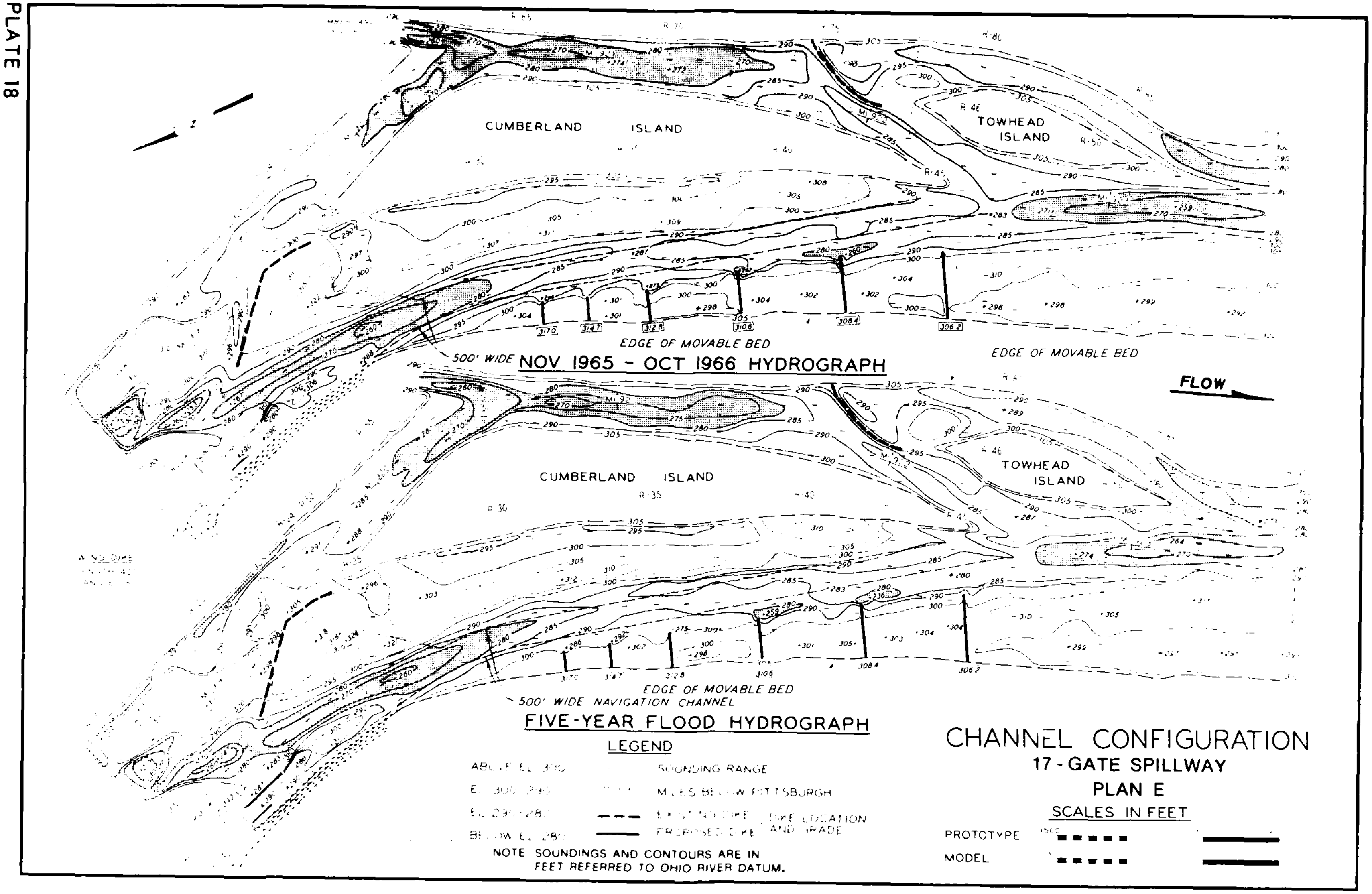


CHANNEL CONFIGURATION
17-GATE SPILLWAY
PLAN D RUN 7

PLATE 16



CHANNEL CONFIGURATION
17-GATE SPILLWAY
PLANS D-1 AND D-2


CHANNEL CONFIGURATION
17-GATE SPILLWAY
PLAN E
NOV 1965 - OCT 1966 HYDROGRAPH
FIVE-YEAR FLOOD HYDROGRAPH
CUMBERLAND ISLAND
TOWHEAD ISLAND
EDGE OF MOVABLE BED
500' WIDE NAVIGATION CHANNEL
FLOW
LEGEND
SOUNDING RANGE
MILES BELOW PITTSBURGH
DIKE LOCATION AND GRADE
NOTE SOUNDINGS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
SCALES IN FEET
PROTOTYPE
MODEL

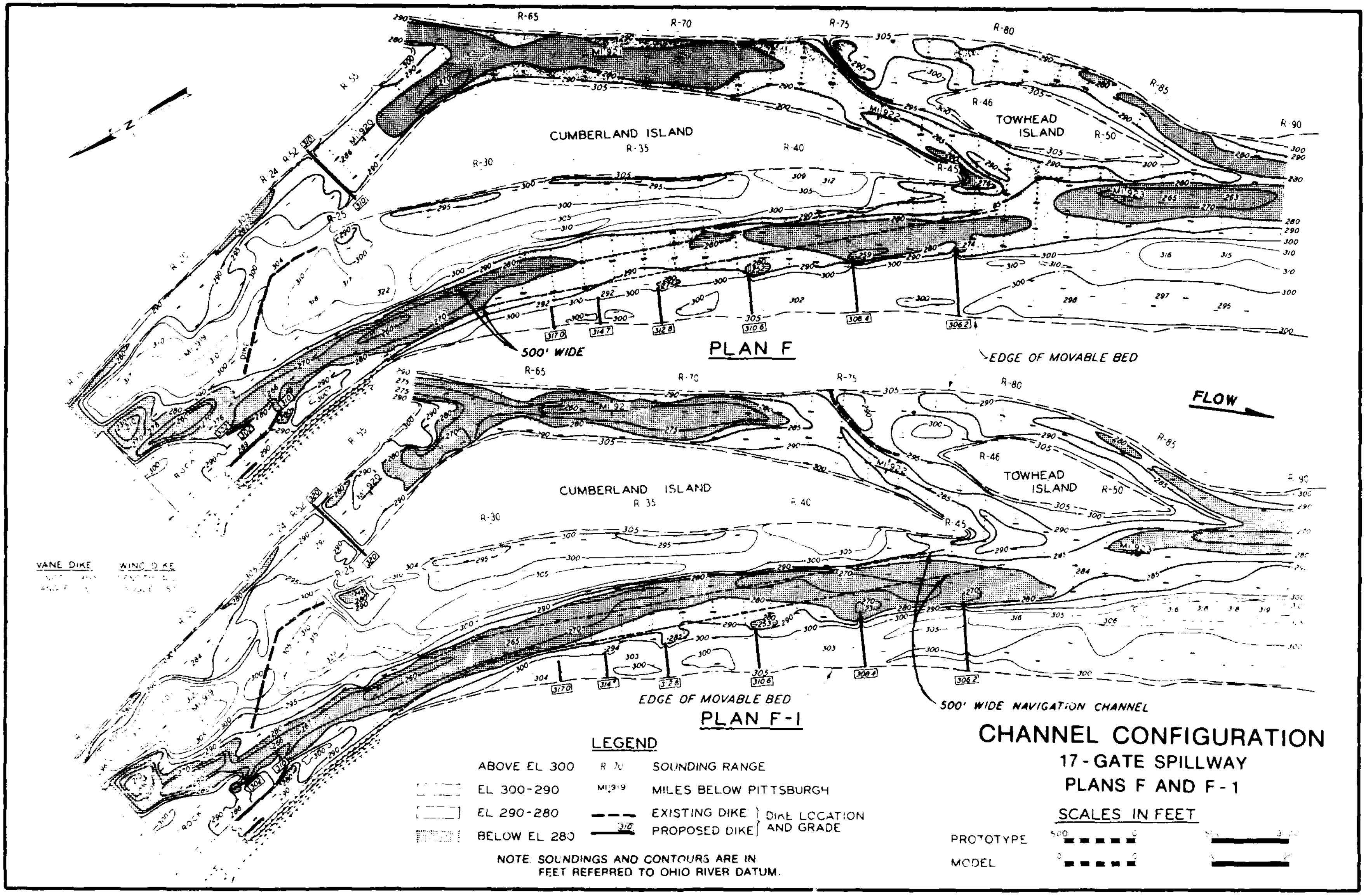
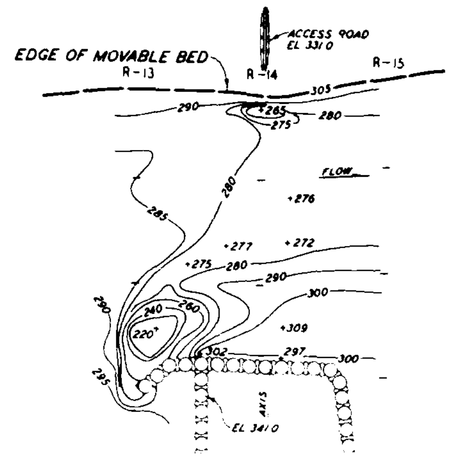
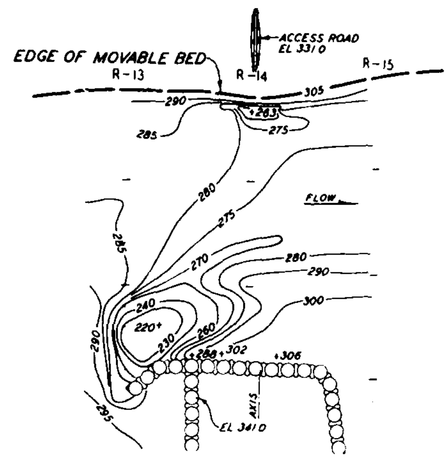

PLAN F
PLAN F-1
CUMBERLAND ISLAND
TOWHEAD ISLAND
FLOW
500' WIDE
500' WIDE NAVIGATION CHANNEL
EDGE OF MOVABLE BED
VANE DIKE
WING DIKE
LEGEND
ABOVE EL 300
EL 300-290
EL 290-280
BELOW EL 280
SOUNDING RANGE
MILES BELOW PITTSBURGH
EXISTING DIKE
PROPOSED DIKE
DIKE LOCATION AND GRADE
NOTE SOUNDINGS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
CHANNEL CONFIGURATION
17-GATE SPILLWAY
PLANS F AND F-1
SCALES IN FEET
PROTOTYPE
MODEL

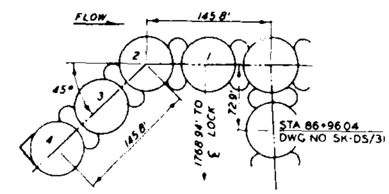
PLATE 19



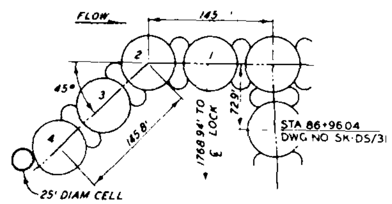
PLAN B
DISCHARGE 615,000 CFS
TAILWATER EL 331.6



PLAN B
DISCHARGE 760,000 CFS
TAILWATER EL 336.1



PLAN B

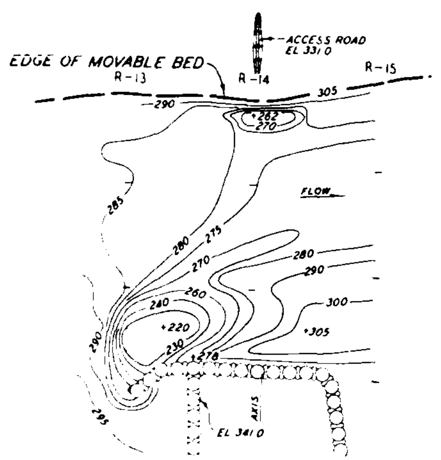


PLAN B-1

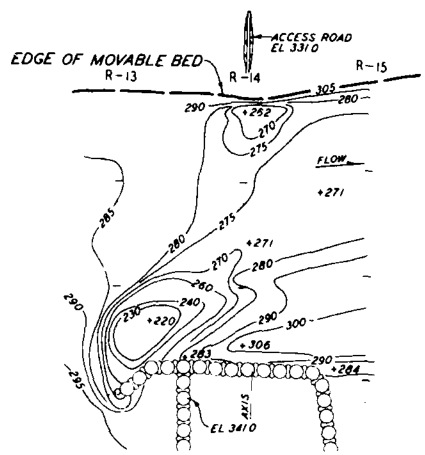
SCALES IN FEET

PROTOTYPE 100 0 100 200
MODEL 0.5 0 0.5 1

NOTE: ELEVATIONS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.



PLAN B
DISCHARGE 855,000 CFS
TAILWATER EL 338.8

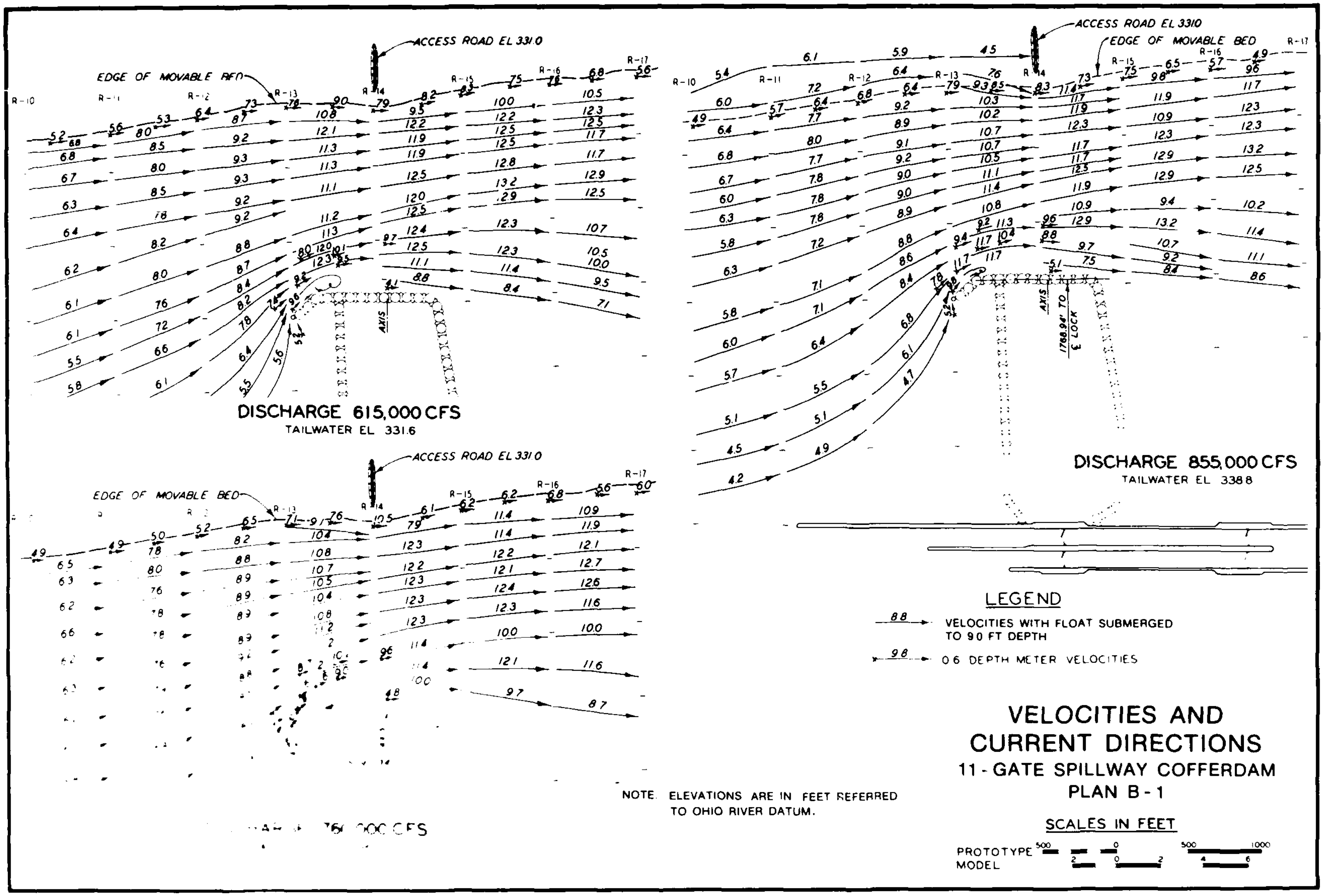


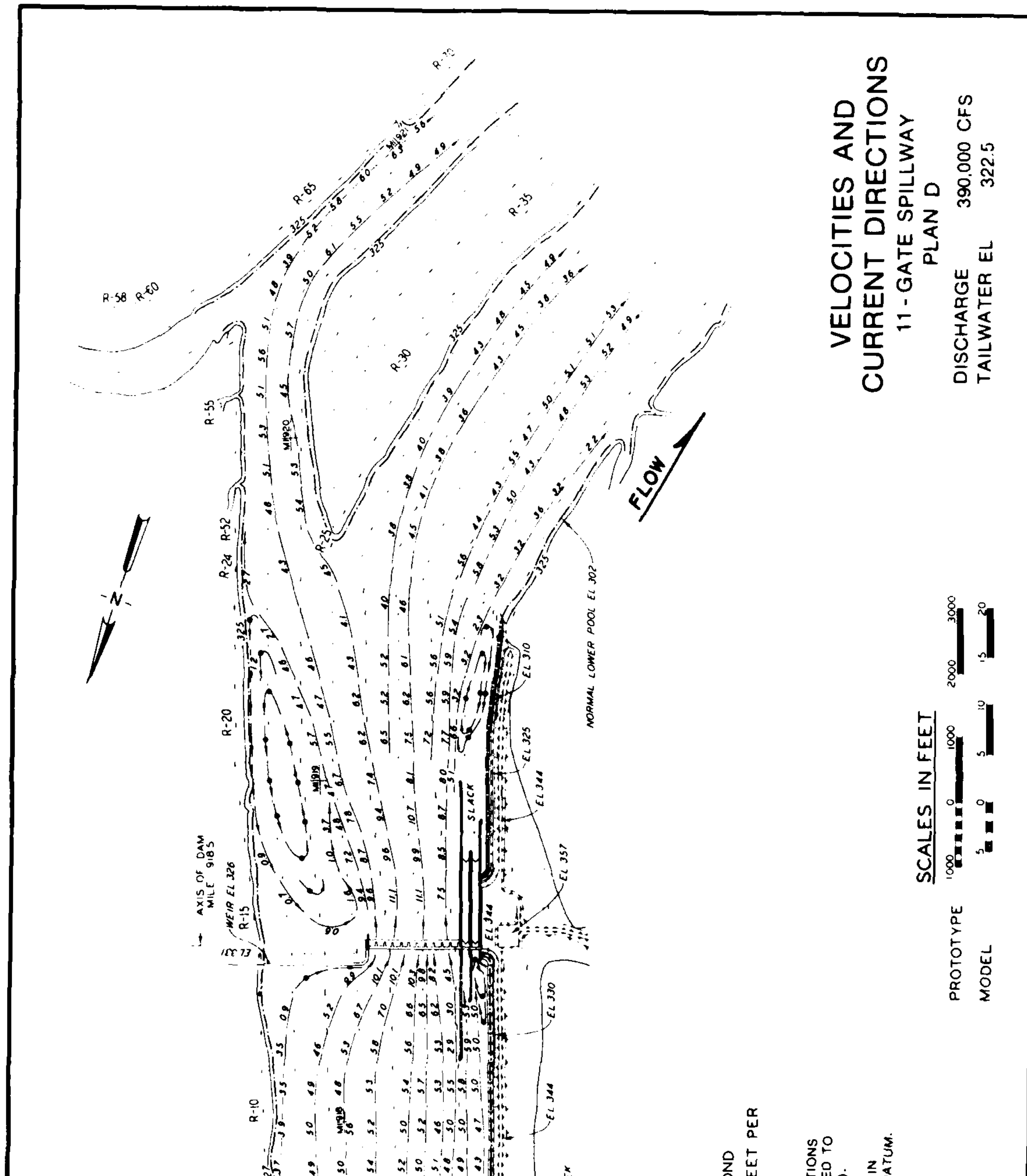
PLAN B-1
DISCHARGE 855,000 CFS
TAILWATER EL 338.8

BED CONFIGURATIONS
11-GATE SPILLWAY COFFERDAM
PLANS B AND B-1

SCALES IN FEET

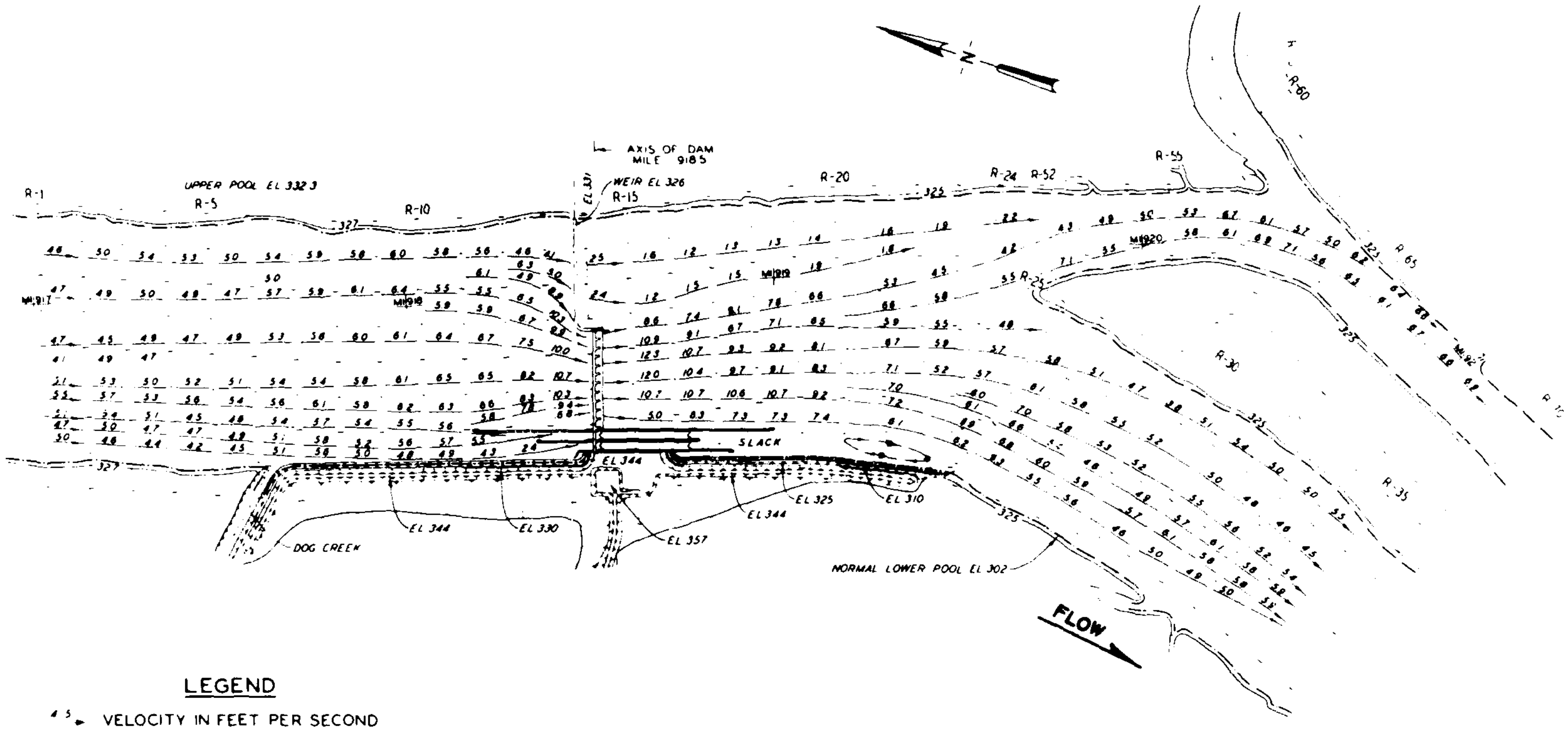
PROTOTYPE 500 0 500 1000
MODEL 2 0 2 4 6


DISCHARGE 615,000 CFS
TAILWATER EL 331.6
DISCHARGE 855,000 CFS
TAILWATER EL 338.8
ACCESS ROAD EL 331.0
EDGE OF MOVABLE BED
AXIS
1788.94' TO ℄ LOCK
LEGEND
VELOCITIES WITH FLOAT SUBMERGED TO 9.0 FT DEPTH
0.6 DEPTH METER VELOCITIES
NOTE: ELEVATIONS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
VELOCITIES AND CURRENT DIRECTIONS
11-GATE SPILLWAY COFFERDAM
PLAN B-1
SCALES IN FEET
PROTOTYPE
MODEL



VELOCITIES AND CURRENT DIRECTIONS
11-GATE SPILLWAY
PLAN D
DISCHARGE 390,000 CFS
TAILWATER EL 322.5
SCALES IN FEET
PROTOTYPE
MODEL
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.
FLOW
N
AXIS OF DAM MILE 918.5
WEIR EL 326
UPPER POOL EL 324.0
NORMAL LOWER POOL EL 302
SLACK
DOG CREEK
EL 310
EL 325
EL 344
EL 357
EL 330

PLATE 22



LEGEND

4.5 → VELOCITY IN FEET PER SECOND

• • VELOCITY LESS THAN 0.5 FEET PER SECOND

NOTE: VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (9.0 FT).

ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM.

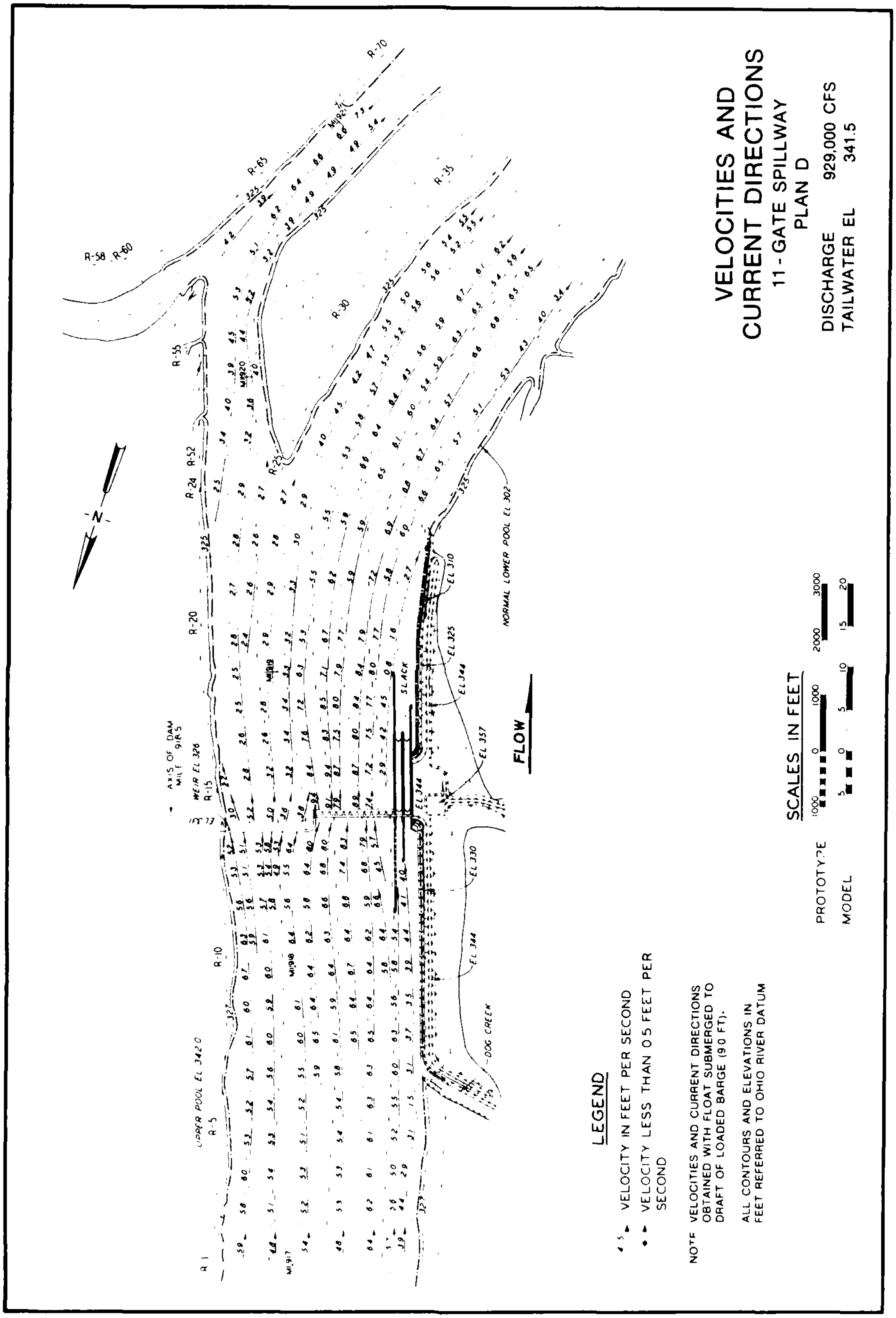
SCALES IN FEET

PROTOTYPE 1000 0 1000 2000 3000

MODEL 5 0 5 10 15 20

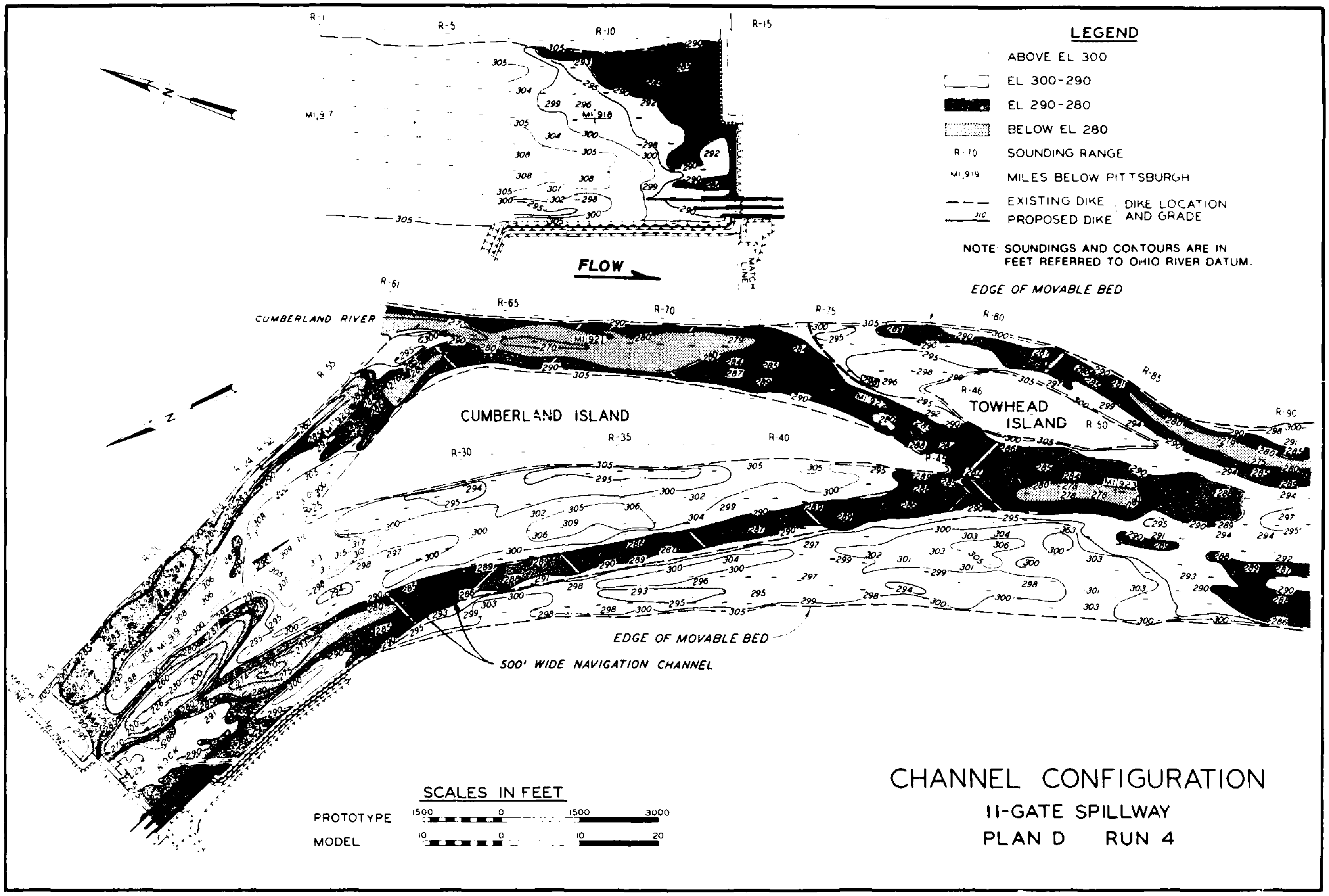
VELOCITIES AND CURRENT DIRECTIONS
11-GATE SPILLWAY
PLAN D

DISCHARGE 600,000 CFS
TAILWATER EL 330.9

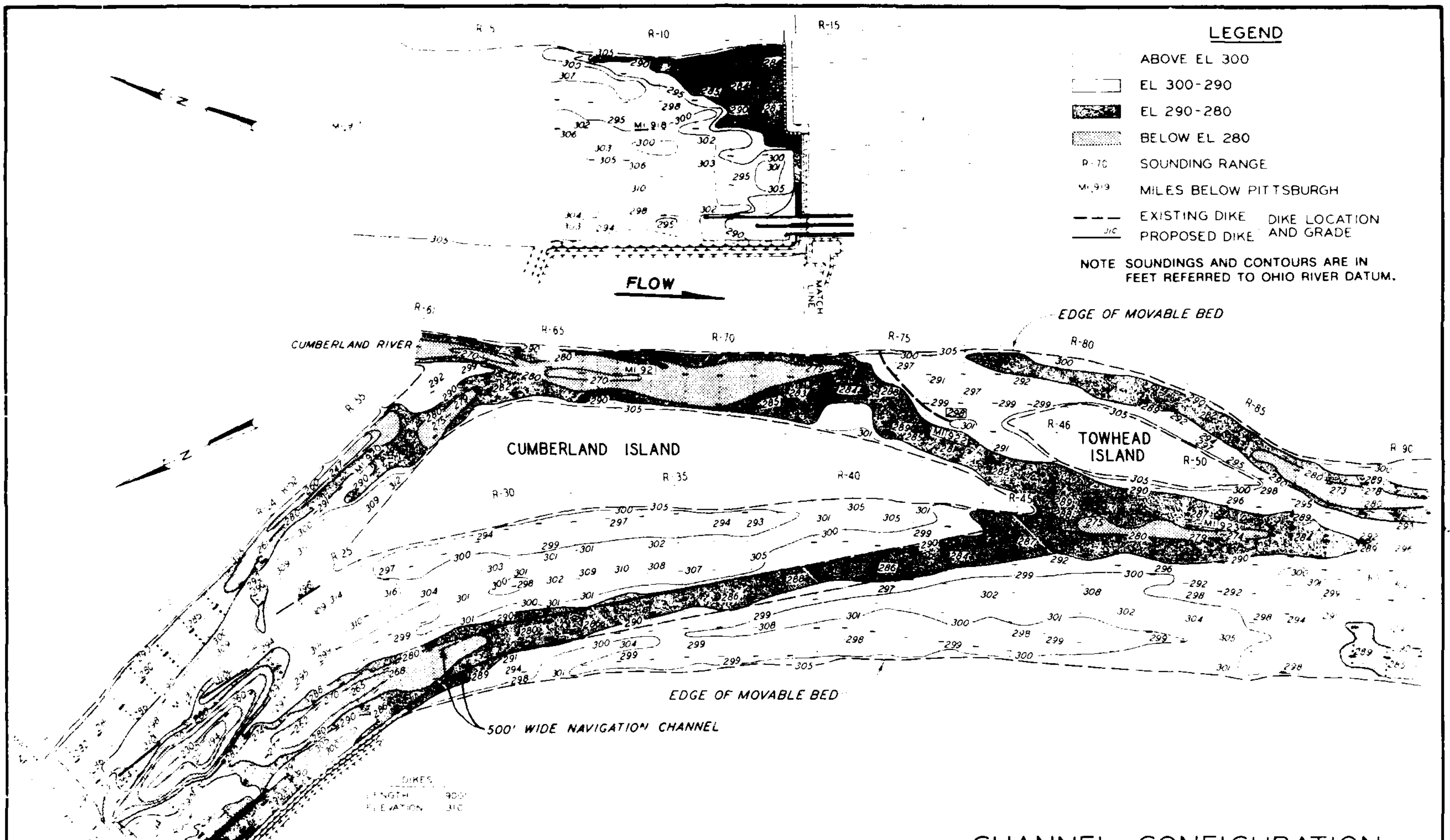


VELOCITIES AND CURRENT DIRECTIONS
11-GATE SPILLWAY
PLAN D
DISCHARGE 929,000 CFS
TAILWATER EL 341.5
LEGEND
VELOCITY IN FEET PER SECOND
VELOCITY LESS THAN 0.5 FEET PER SECOND
NOTE VELOCITIES AND CURRENT DIRECTIONS OBTAINED WITH FLOAT SUBMERGED TO DRAFT OF LOADED BARGE (90 FT).
ALL CONTOURS AND ELEVATIONS IN FEET REFERRED TO OHIO RIVER DATUM
SCALES IN FEET
PROTOTYPE 1000 0 1000 2000 3000
MODEL 5 0 5 10 15 20
FLOW
N
AXIS OF DAM MILE 918.5
WEIR EL 326
UPPER POOL EL 342.0
NORMAL LOWER POOL EL 302
DOG CREEK
SLACK
EL 310
EL 325
EL 344
EL 357
EL 330

PLATE 24

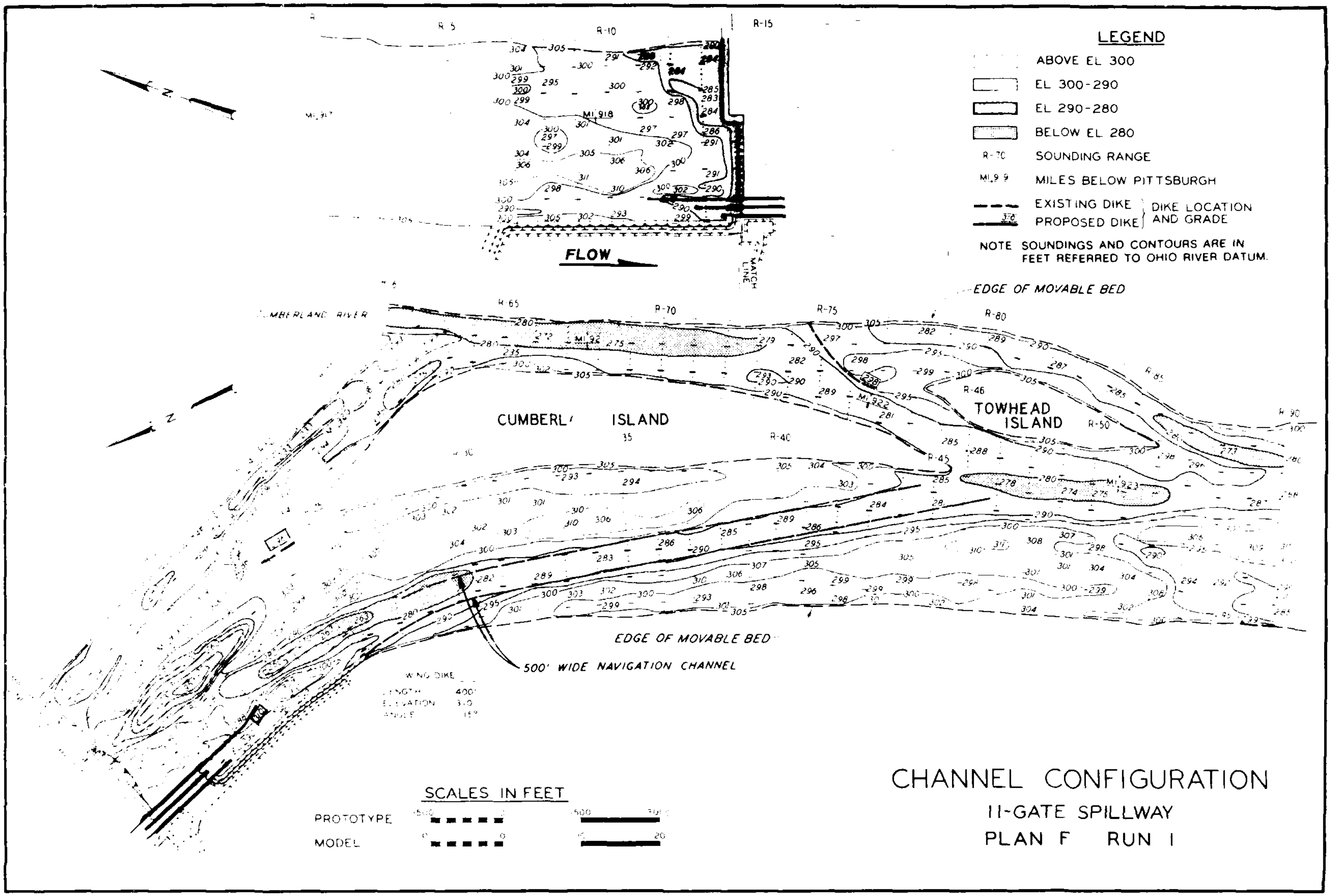


CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN D RUN 4

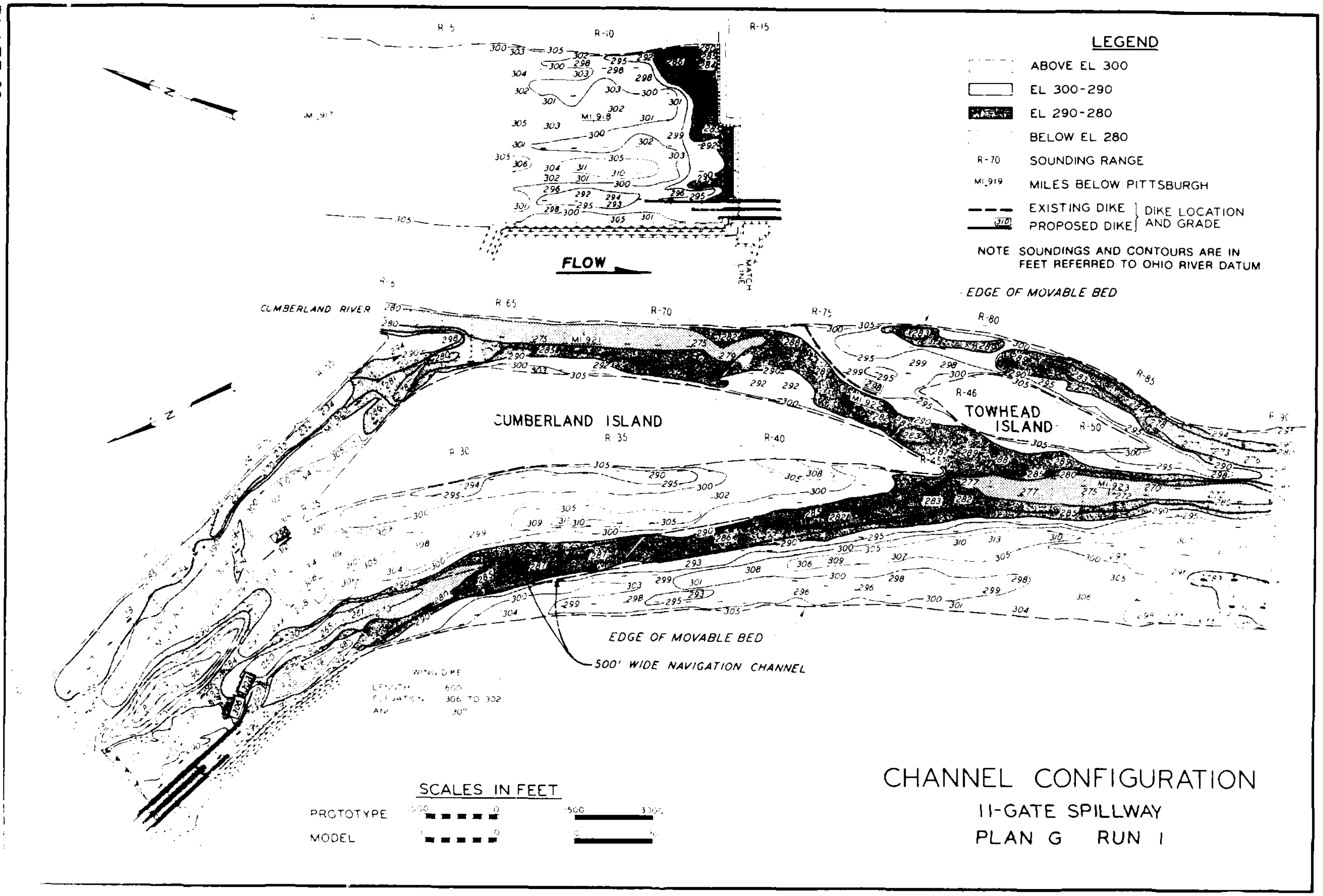


CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN E RUN 1

PLATE 26



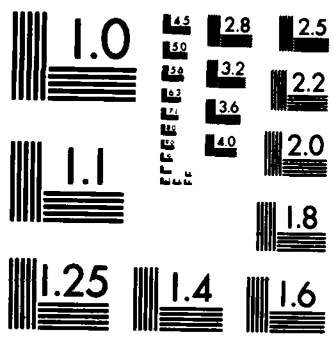
CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN F RUN 1

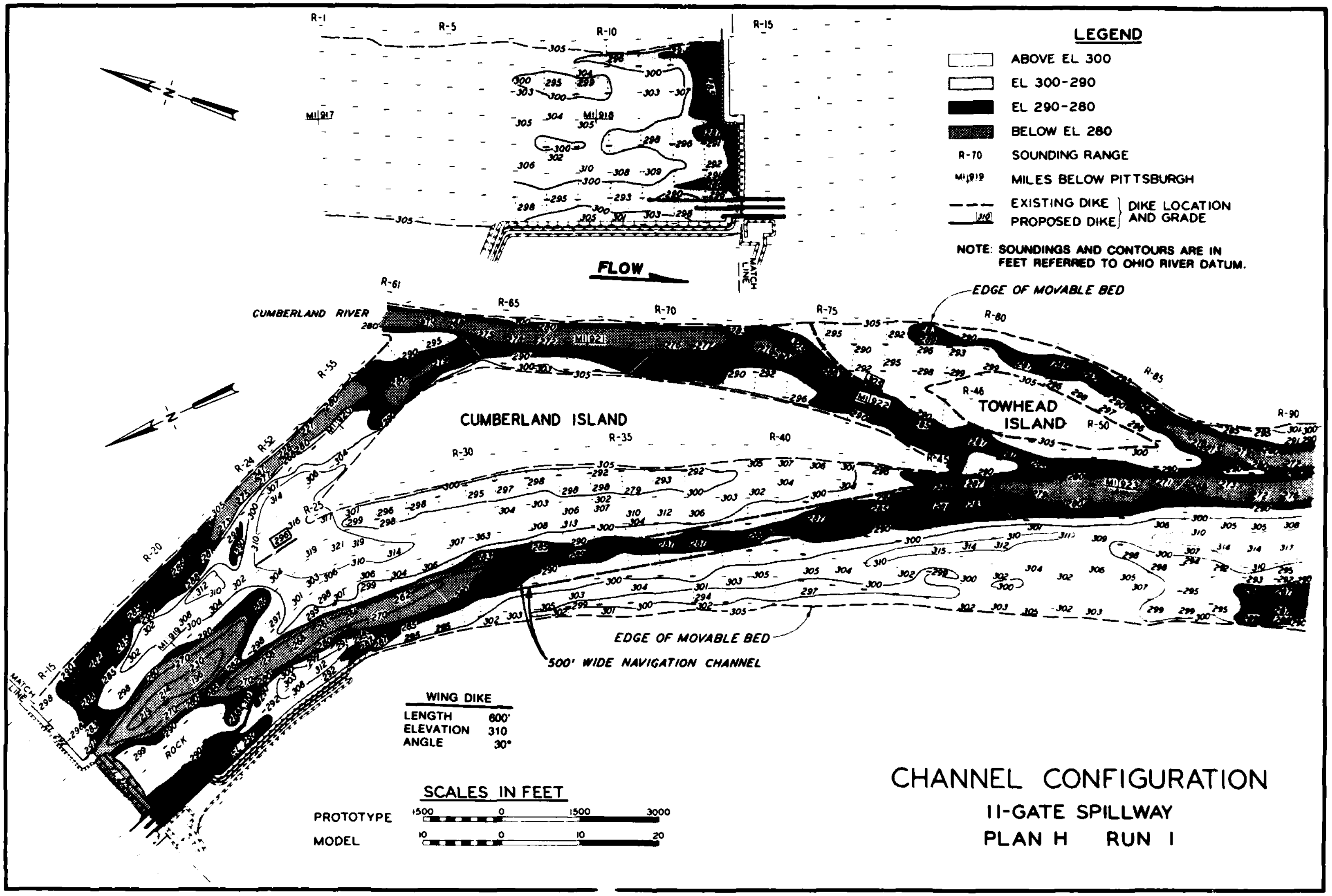


CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN G RUN 1

AD-A137 178 SMITHLAND LOCKS AND DAM OHIO RIVER; HYDRAULIC MODEL INVESTIGATION(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS HYD.. J J FRANCO ET AL. OCT 83 2/2

UNCLASSIFIED WES/TR/HL-83-19 F/G 13/2 NL


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6



CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN H RUN 1

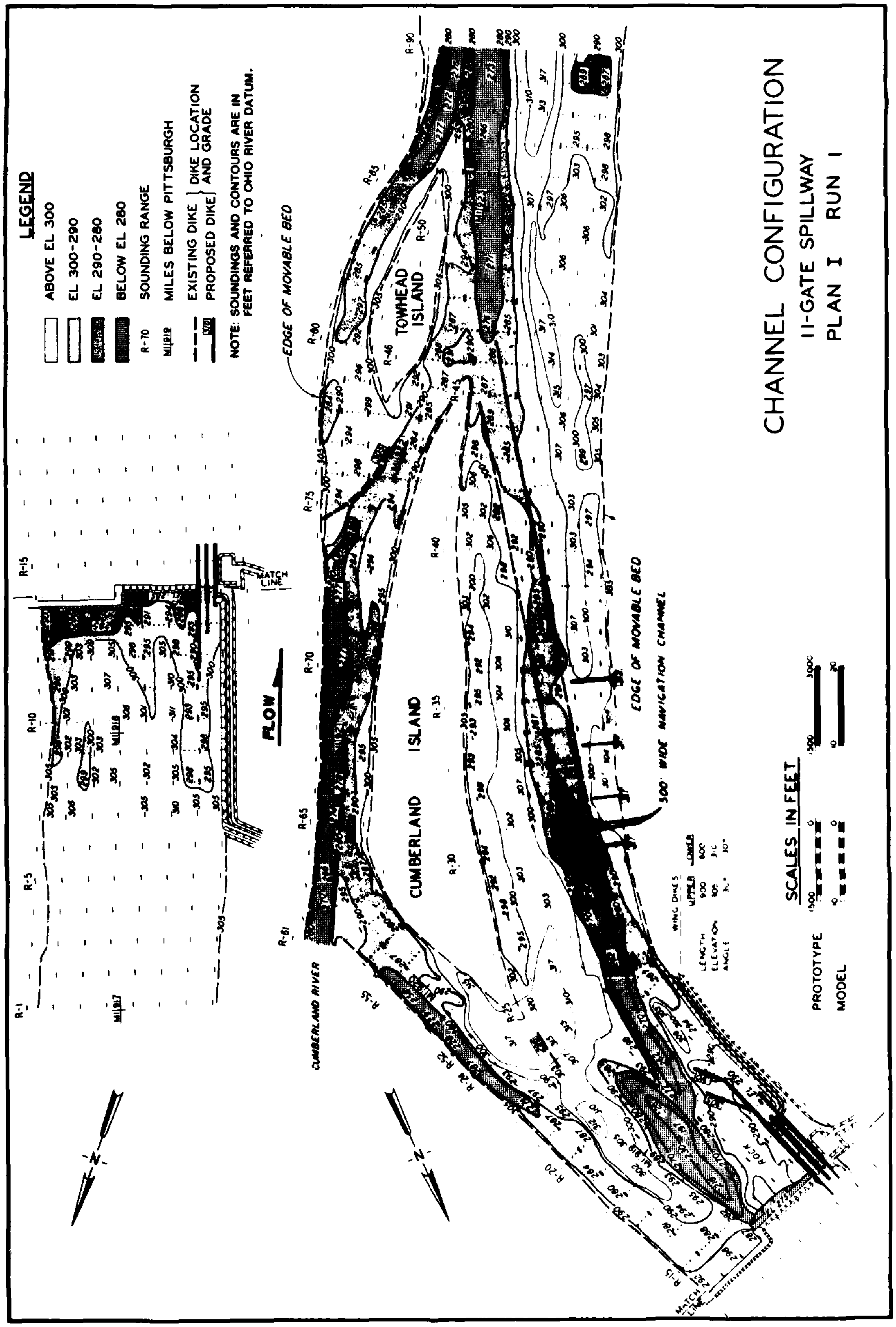
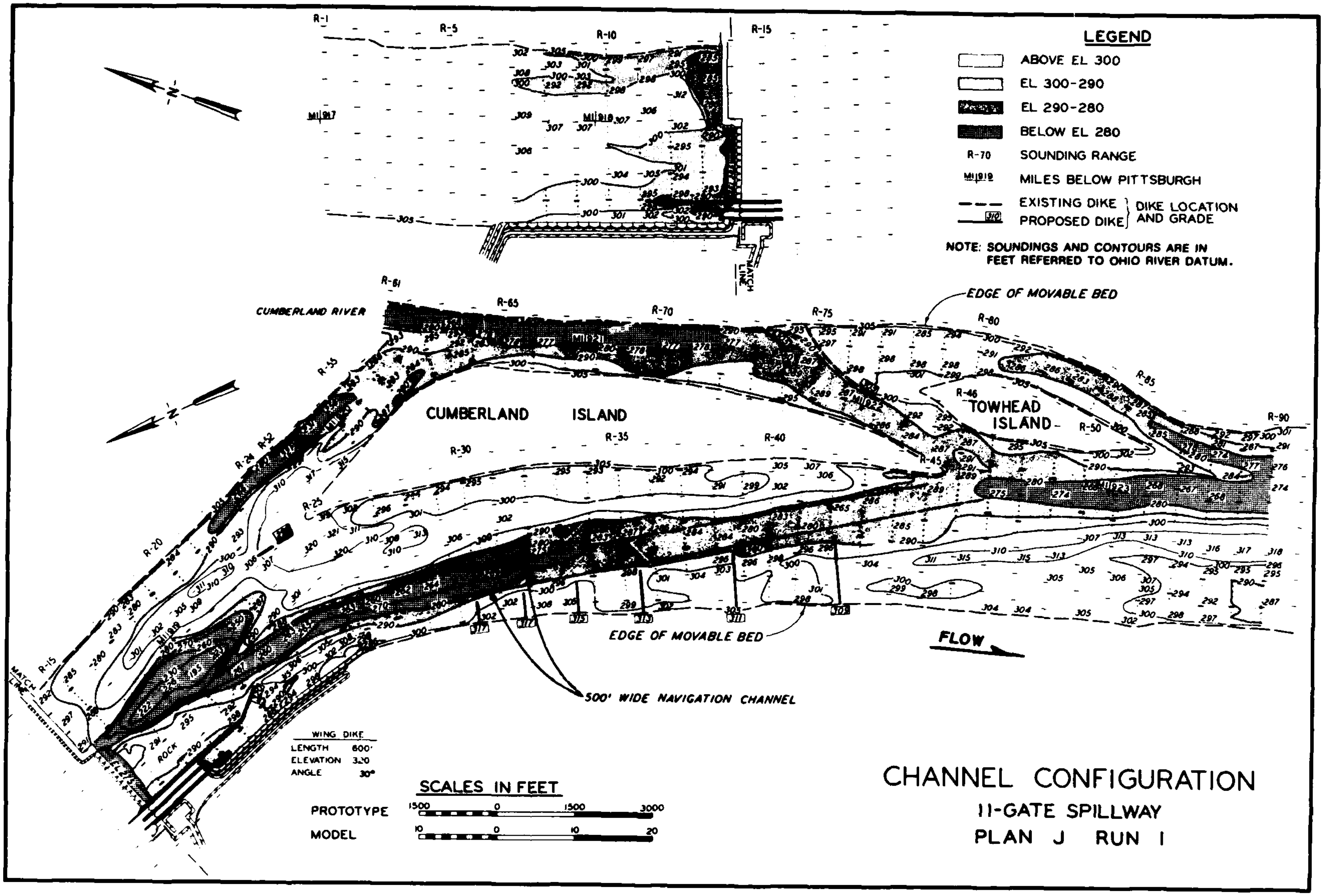
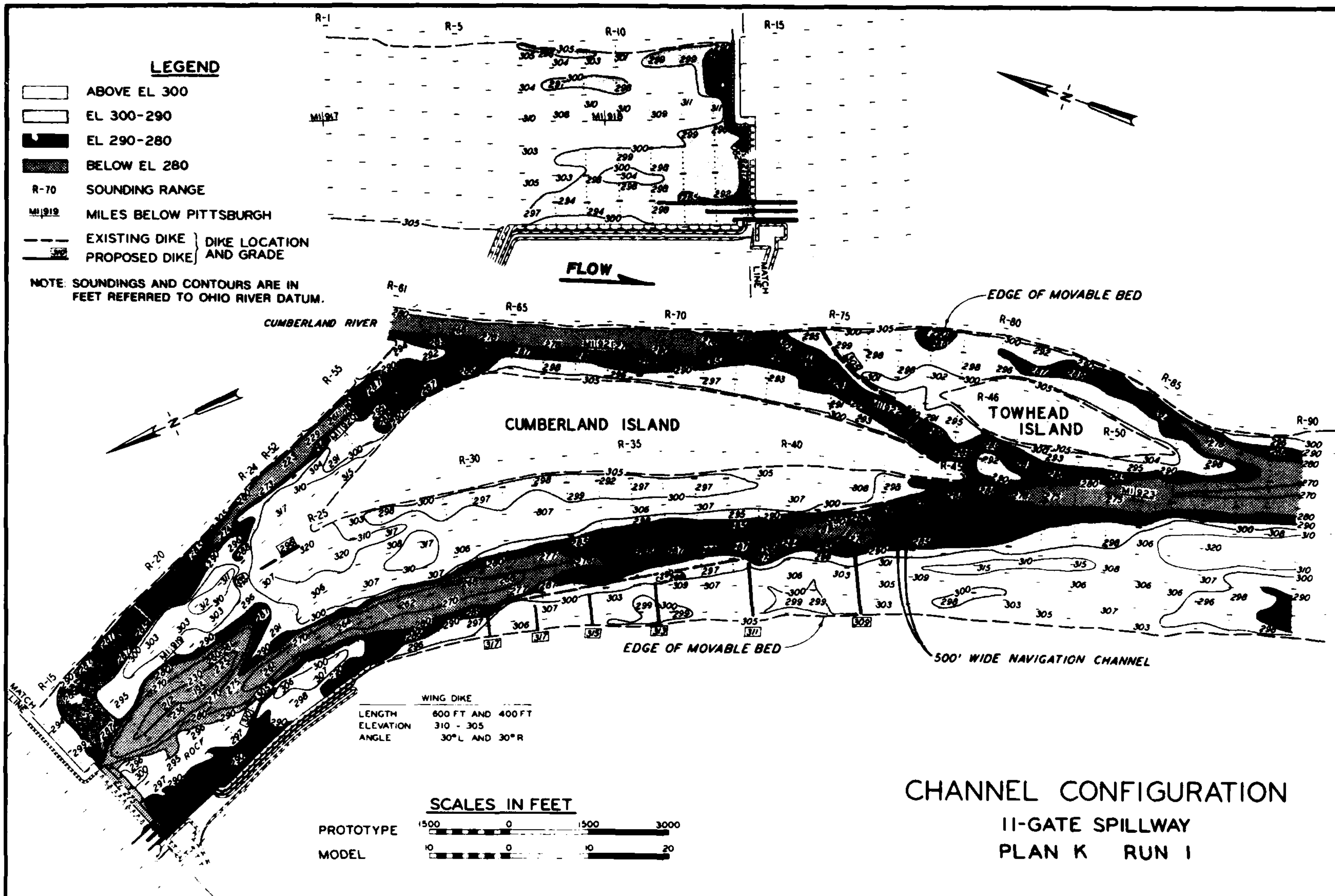

LEGEND
ABOVE EL 300
EL 300-290
EL 290-280
BELOW EL 280
SOUNDING RANGE
MILES BELOW PITTSBURGH
EXISTING DIKE
PROPOSED DIKE
DIKE LOCATION AND GRADE
NOTE: SOUNDINGS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
FLOW
TOWHEAD ISLAND
CUMBERLAND ISLAND
CUMBERLAND RIVER
EDGE OF MOVABLE BED
EDGE OF MOVABLE BED
500' WIDE NAVIGATION CHANNEL
MATCH LINE
SCALES IN FEET
PROTOTYPE
MODEL
CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN I RUN I

PLATE 30

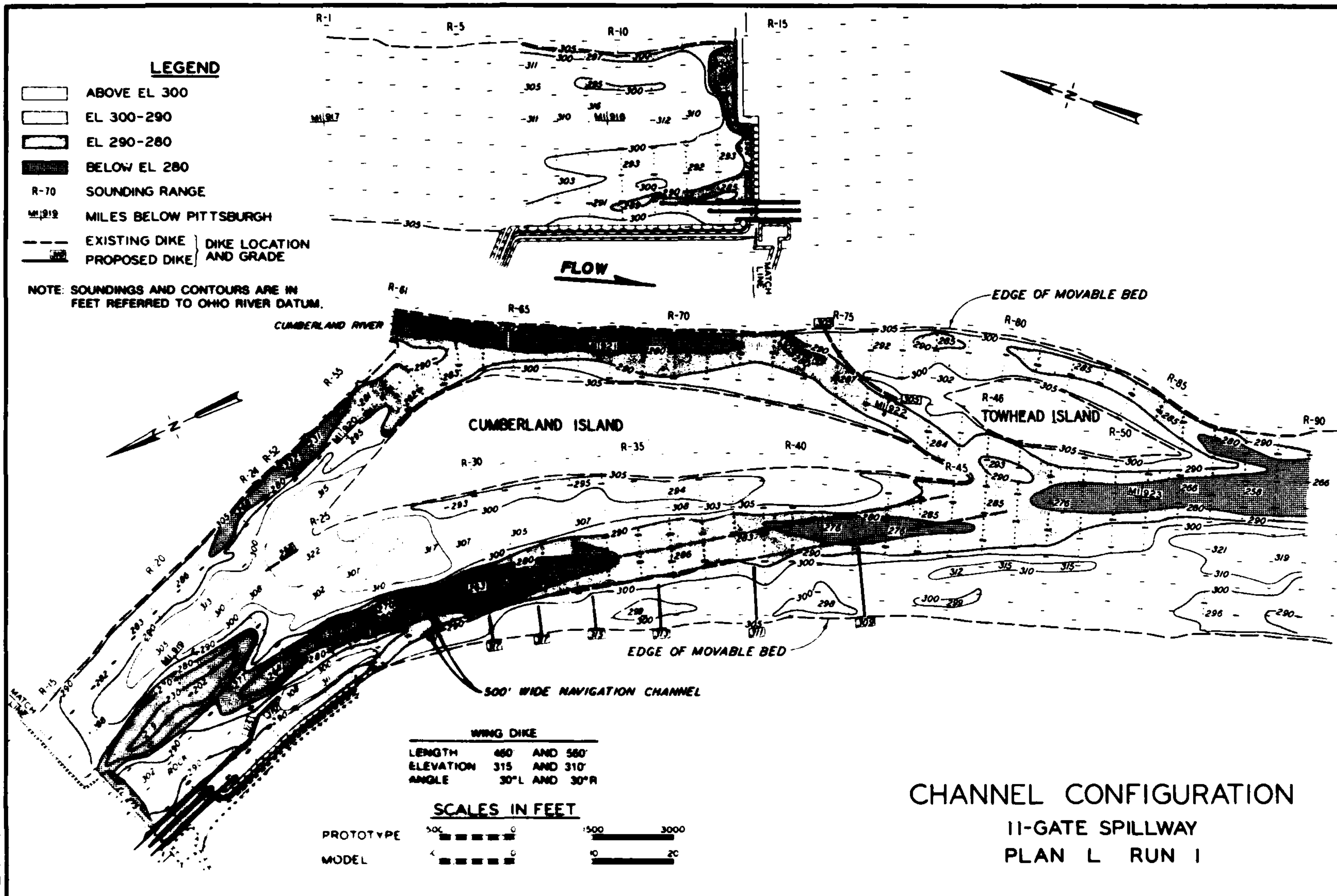


CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN J RUN I

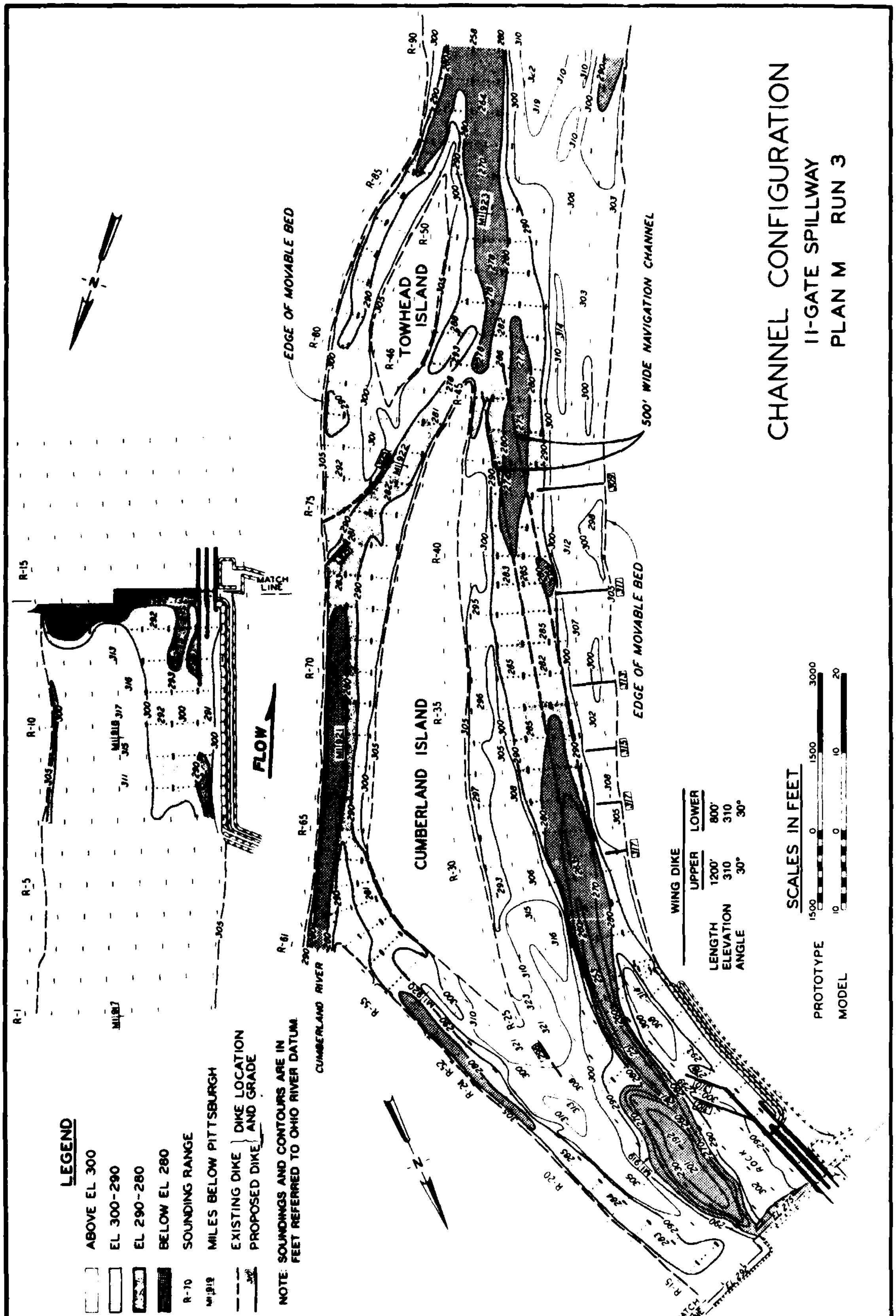
PLATE 32



CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN K RUN 1

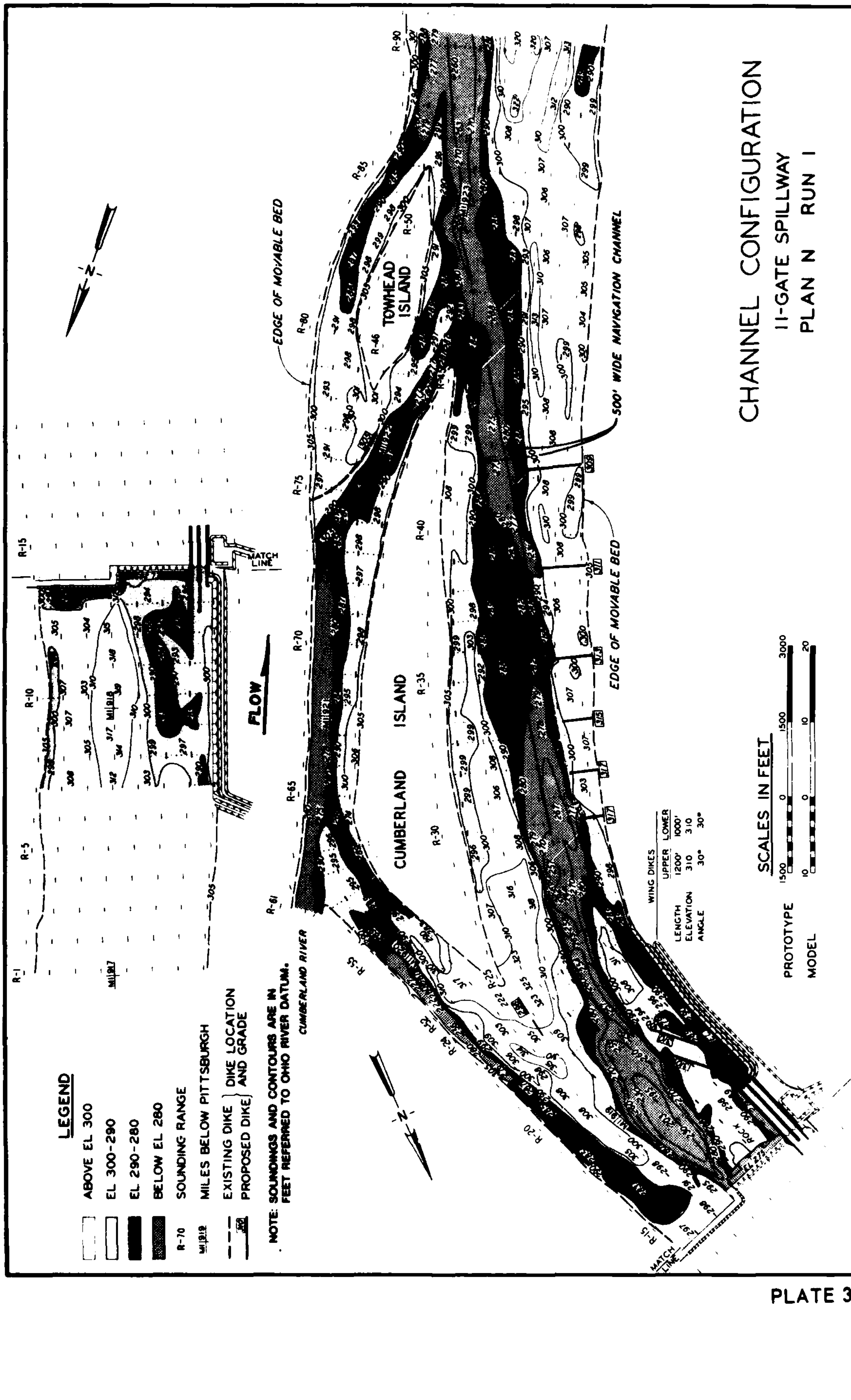


CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN L RUN 1



CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN M RUN 3
LEGEND
ABOVE EL 300
EL 300-290
EL 290-280
BELOW EL 280
SOUNDING RANGE
MILES BELOW PITTSBURGH
EXISTING DIKE
PROPOSED DIKE
DIKE LOCATION AND GRADE
NOTE: SOUNDINGS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
WING DIKE
UPPER
LOWER
LENGTH
ELEVATION
ANGLE
1200'
310
30°
800'
310
30°
SCALES IN FEET
PROTOTYPE
MODEL
1500
0
1500
3000
10
0
10
20
CUMBERLAND ISLAND
TOWHEAD ISLAND
CUMBERLAND RIVER
EDGE OF MOVABLE BED
500' WIDE NAVIGATION CHANNEL
FLOW
MATCH LINE

PLATE 34



CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN N RUN 1
LEGEND
ABOVE EL 300
EL 300-290
EL 290-280
BELOW EL 280
R-70 SOUNDING RANGE
MI 918 MILES BELOW PITTSBURGH
EXISTING DIKE
PROPOSED DIKE
DIKE LOCATION AND GRADE
NOTE: SOUNDINGS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
CUMBERLAND RIVER
CUMBERLAND ISLAND
TOWHEAD ISLAND
FLOW
EDGE OF MOVABLE BED
500' WIDE NAVIGATION CHANNEL
MATCH LINE
WING DIKES
UPPER LOWER
LENGTH 1200' 1000'
ELEVATION 310 310
ANGLE 30° 30°
SCALES IN FEET
PROTOTYPE 1500 0 1500 3000
MODEL 10 0 10 20

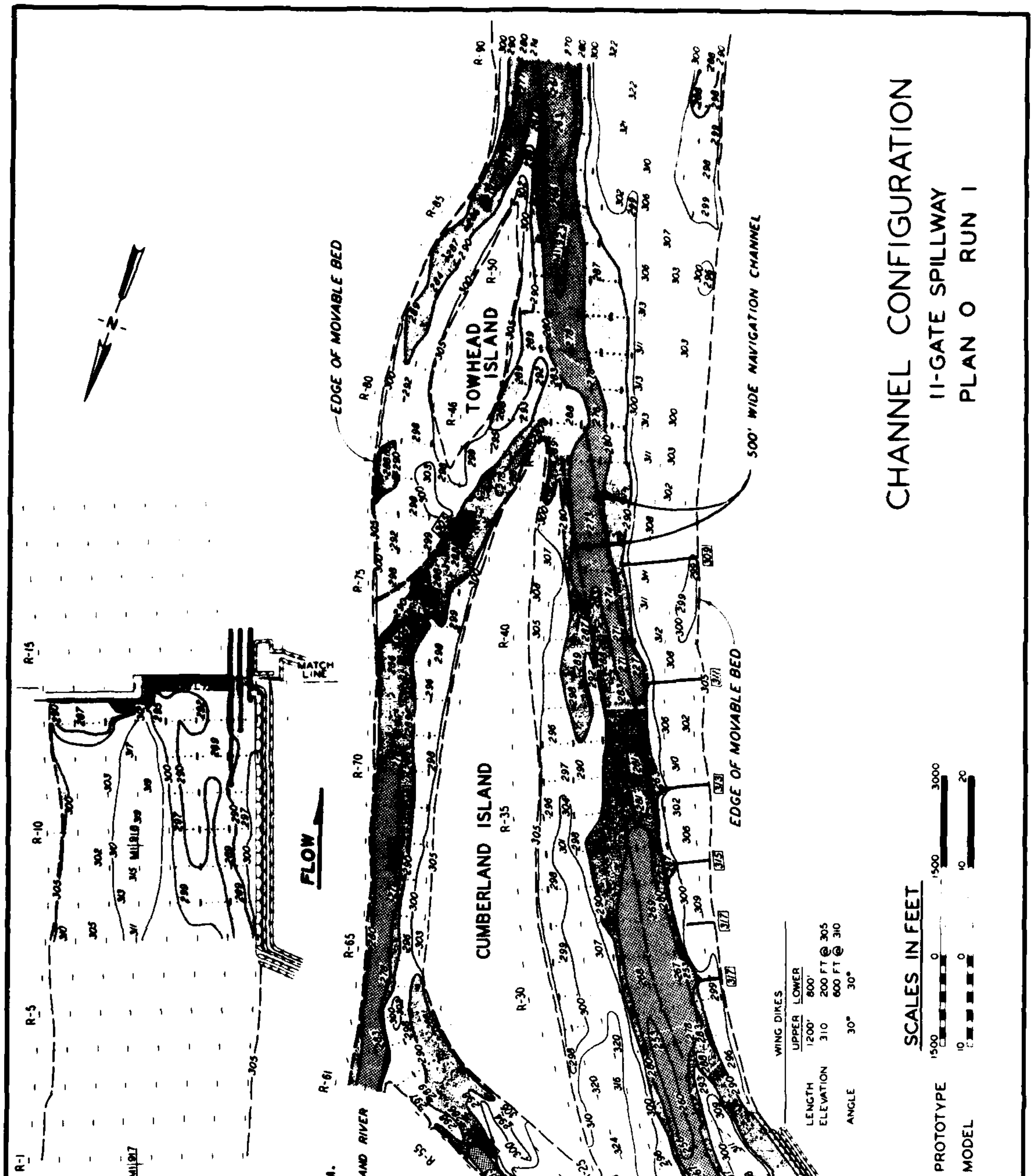
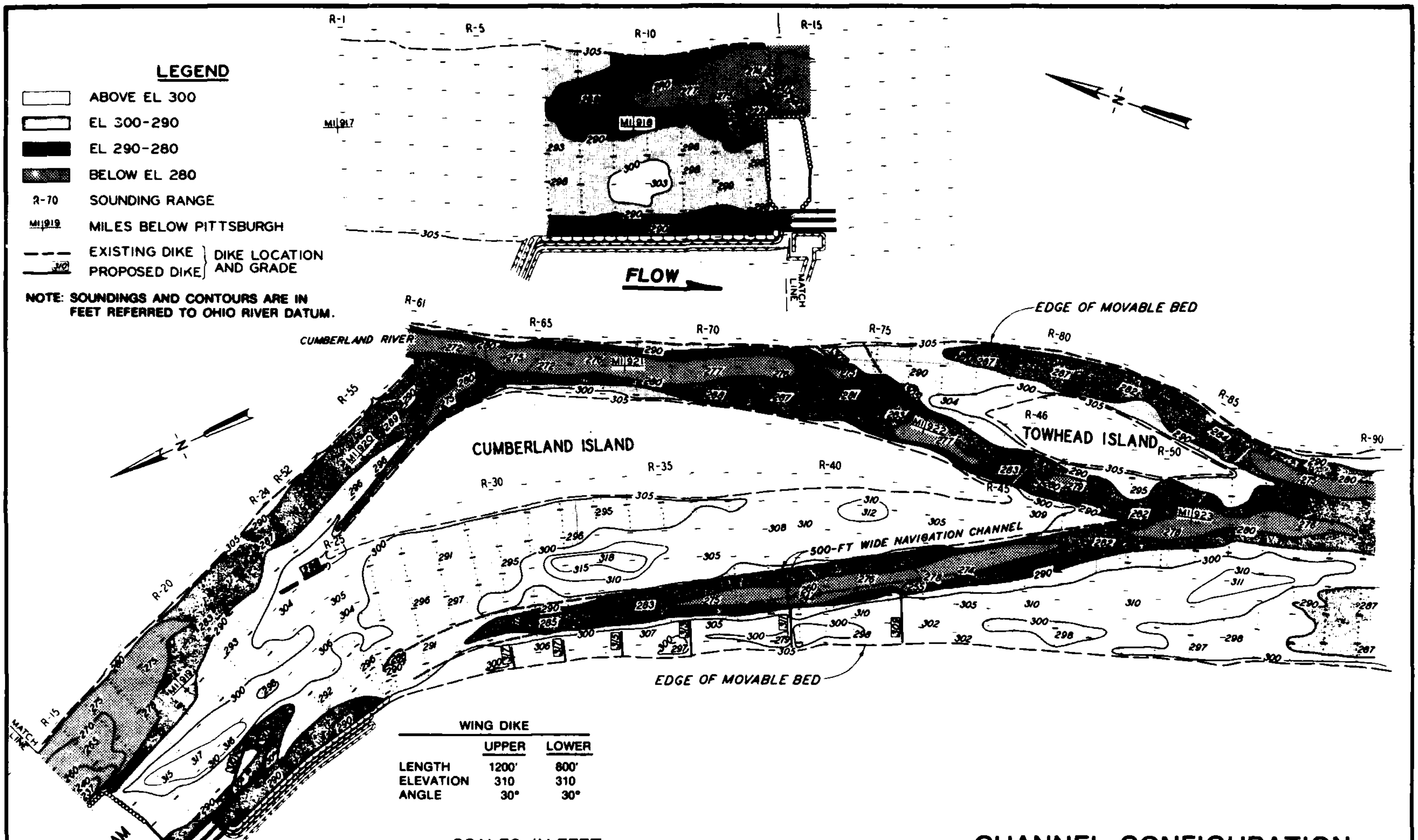

CHANNEL CONFIGURATION
11-GATE SPILLWAY
PLAN O RUN 1
LEGEND
ABOVE EL 300
EL 300-290
EL 290-280
BELOW EL 280
R-70 SOUNDING RANGE
MI 191.9 MILES BELOW PITTSBURGH
EXISTING DIKE
PROPOSED DIKE
DIKE LOCATION AND GRADE
NOTE: SOUNDINGS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
CUMBERLAND RIVER
CUMBERLAND ISLAND
TOWHEAD ISLAND
EDGE OF MOVABLE BED
500' WIDE NAVIGATION CHANNEL
FLOW
MATCH LINE
WING DIKES
UPPER LOWER
LENGTH 1200' 800'
ELEVATION 310 200 FT @ 305 600 FT @ 310
ANGLE 30° 30°
SCALES IN FEET
PROTOTYPE 1500 0 1500 3000
MODEL 10 0 10 20

PLATE 36



CHANNEL CONFIGURATION
11-GATE SPILLWAY
SECOND-PHASE CONSTRUCTION-RUN 1

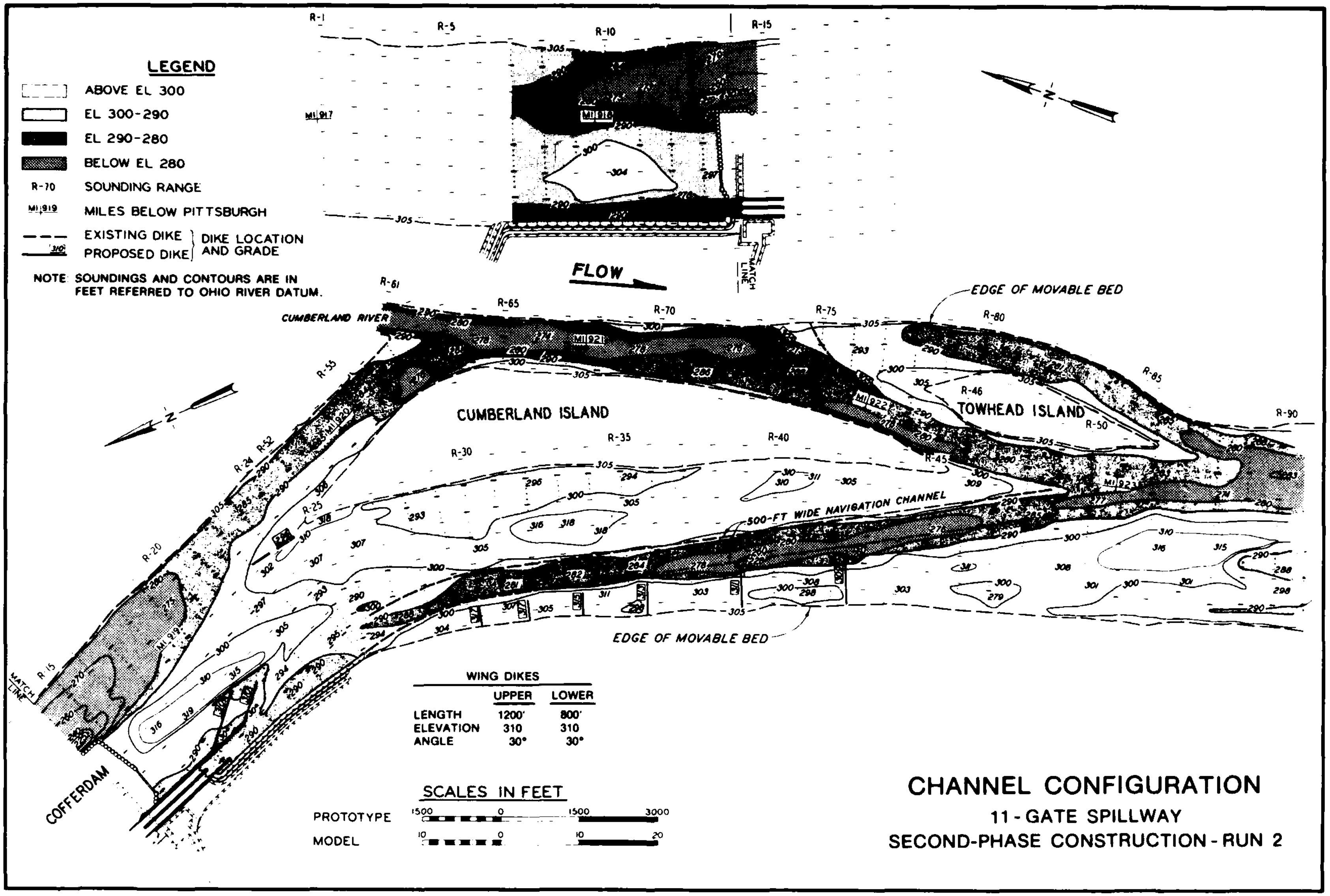
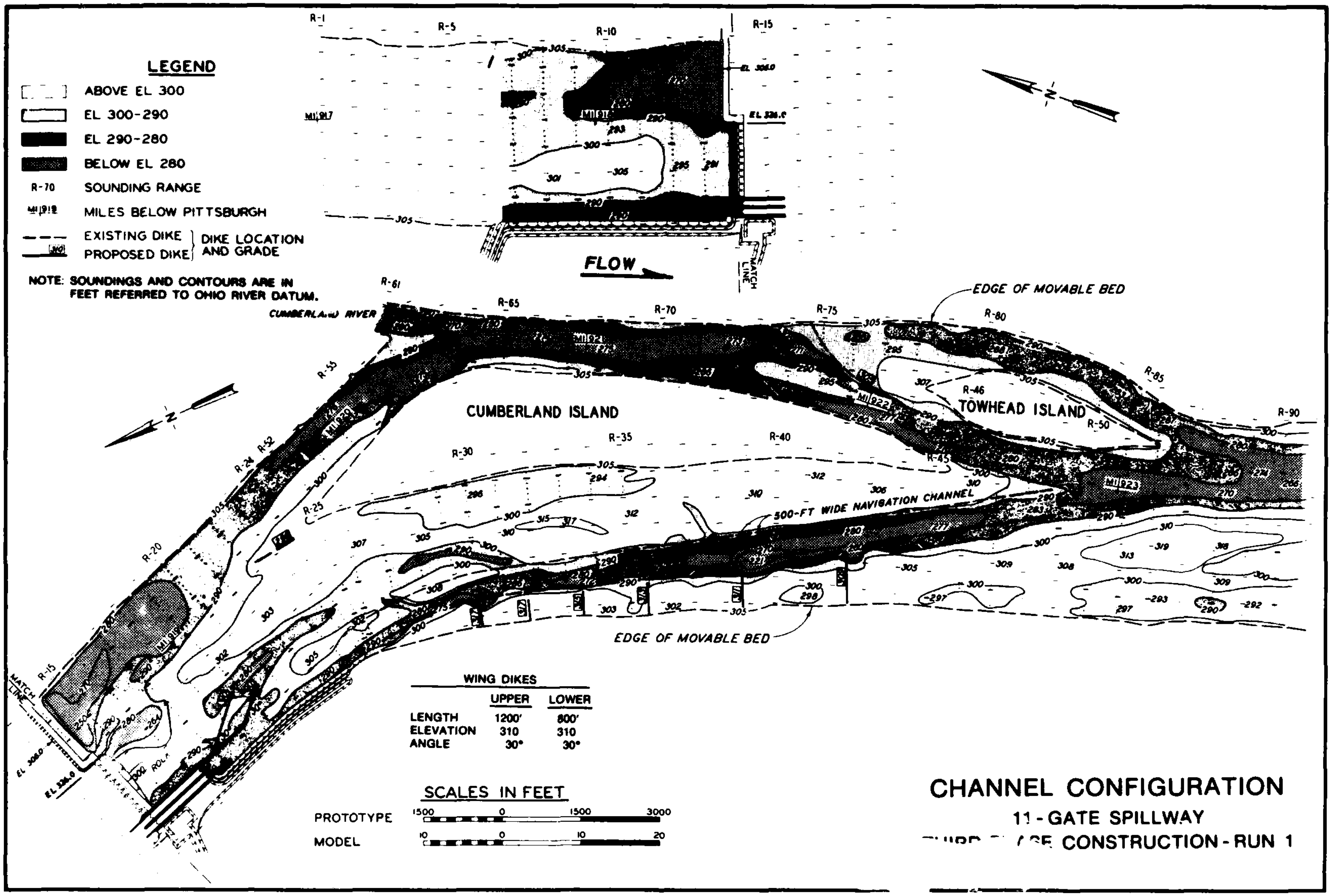
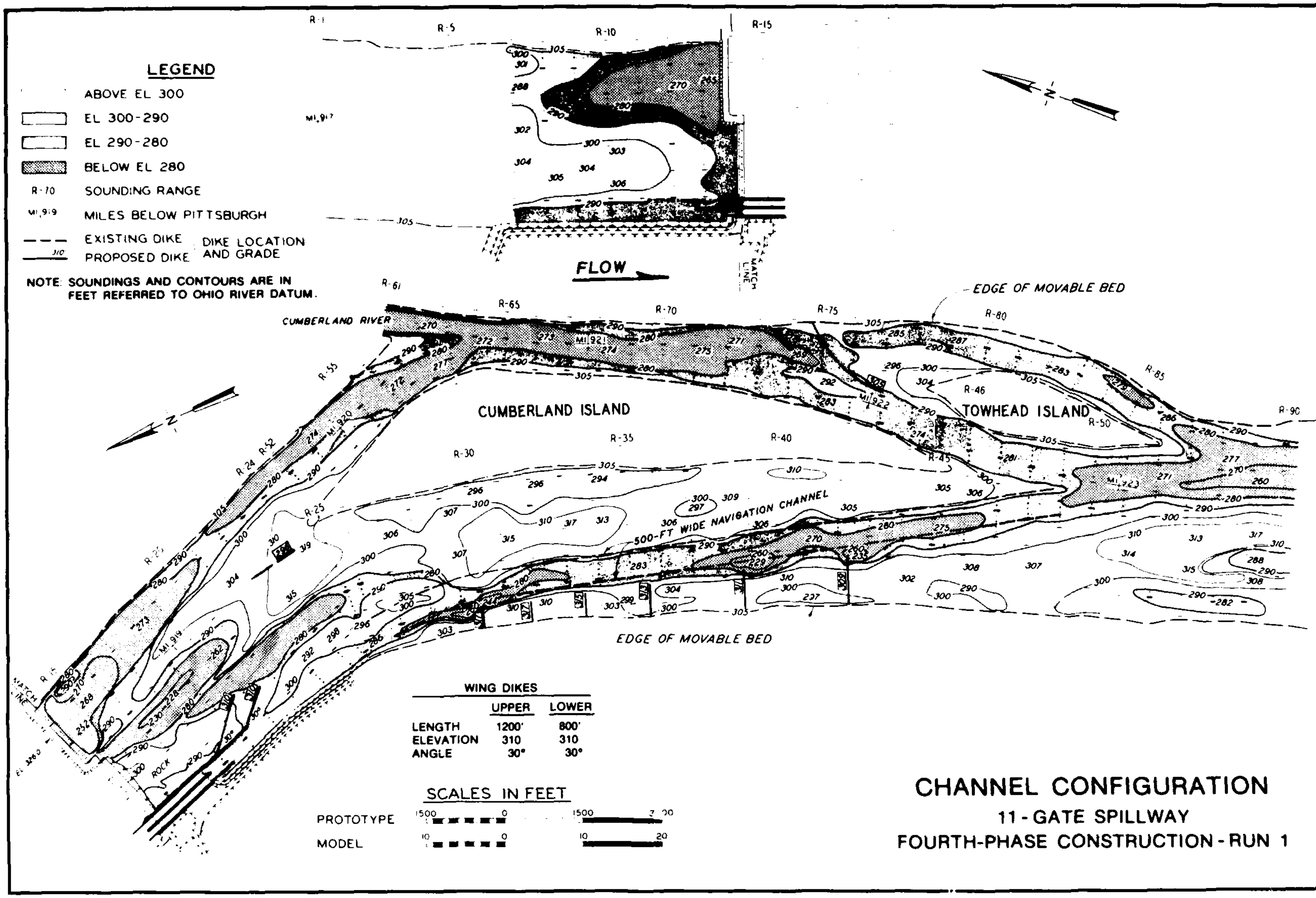

LEGEND
ABOVE EL 300
EL 300-290
EL 290-280
BELOW EL 280
R-70 SOUNDING RANGE
MI 919 MILES BELOW PITTSBURGH
EXISTING DIKE
PROPOSED DIKE
DIKE LOCATION AND GRADE
NOTE: SOUNDINGS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
FLOW
CUMBERLAND RIVER
CUMBERLAND ISLAND
TOWHEAD ISLAND
500-FT WIDE NAVIGATION CHANNEL
EDGE OF MOVABLE BED
EDGE OF MOVABLE BED
COFFERDAM
MATCH LINE
MATCH LINE
N
N
WING DIKES
UPPER LOWER
LENGTH 1200' 800'
ELEVATION 310 310
ANGLE 30° 30°
SCALES IN FEET
PROTOTYPE 1500 0 1500 3000
MODEL 10 0 10 20
CHANNEL CONFIGURATION
11-GATE SPILLWAY
SECOND-PHASE CONSTRUCTION-RUN 2

PLATE 38

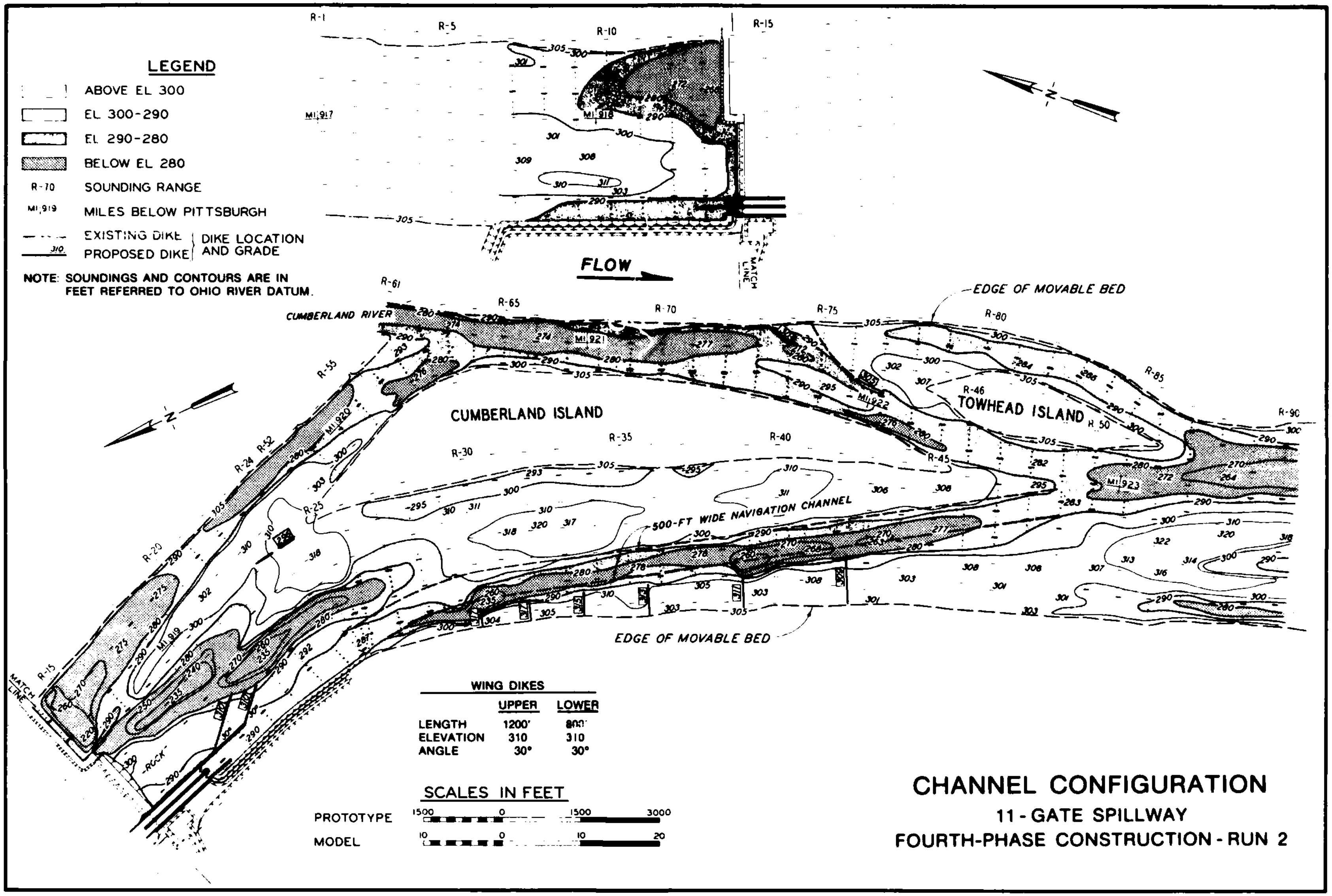


CHANNEL CONFIGURATION
11-GATE SPILLWAY
... CONSTRUCTION-RUN 1

PLATE 39



CHANNEL CONFIGURATION
11-GATE SPILLWAY
FOURTH-PHASE CONSTRUCTION-RUN 1



CHANNEL CONFIGURATION

11 - GATE SPILLWAY

FOURTH-PHASE CONSTRUCTION - RUN 2

PLATE 41

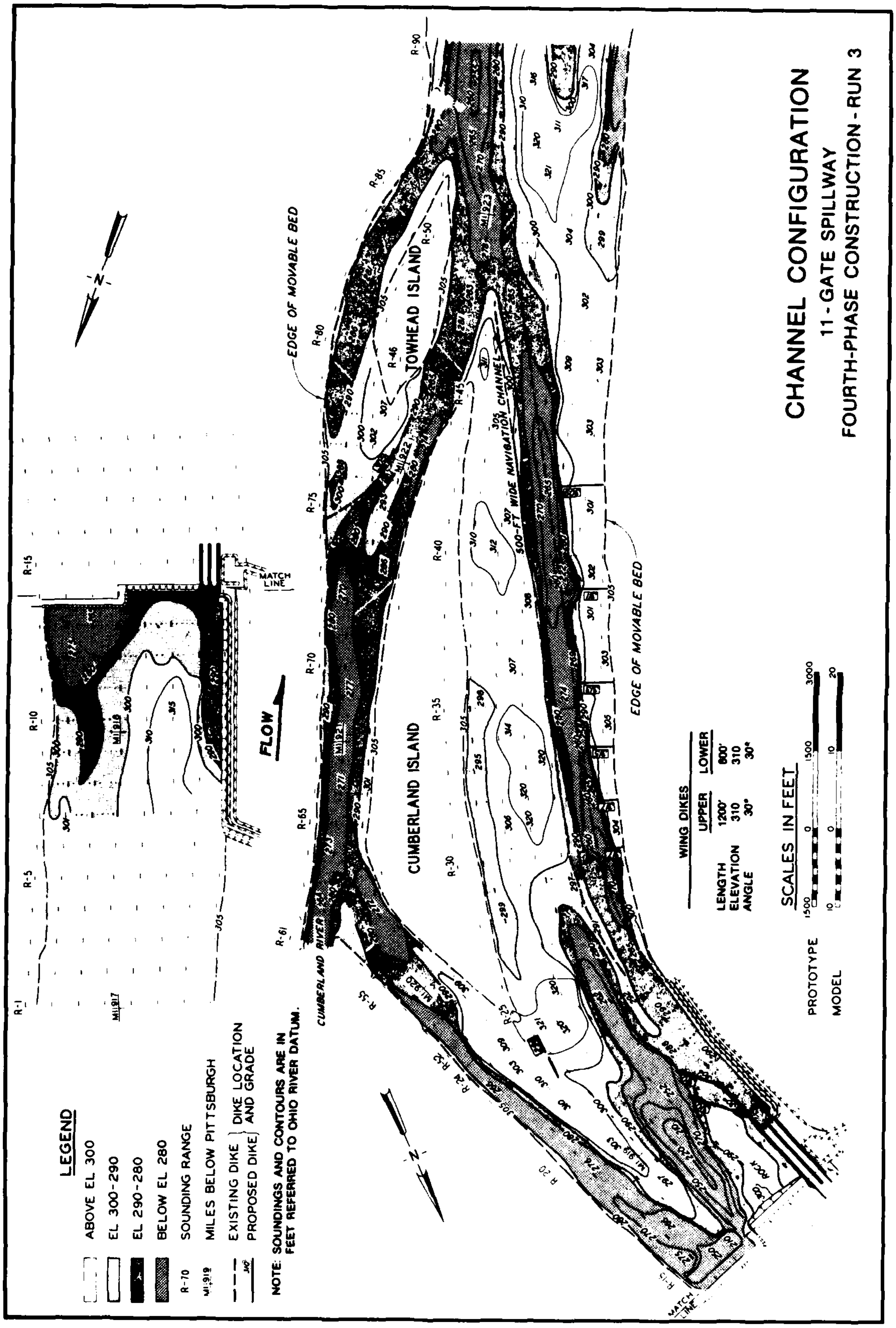
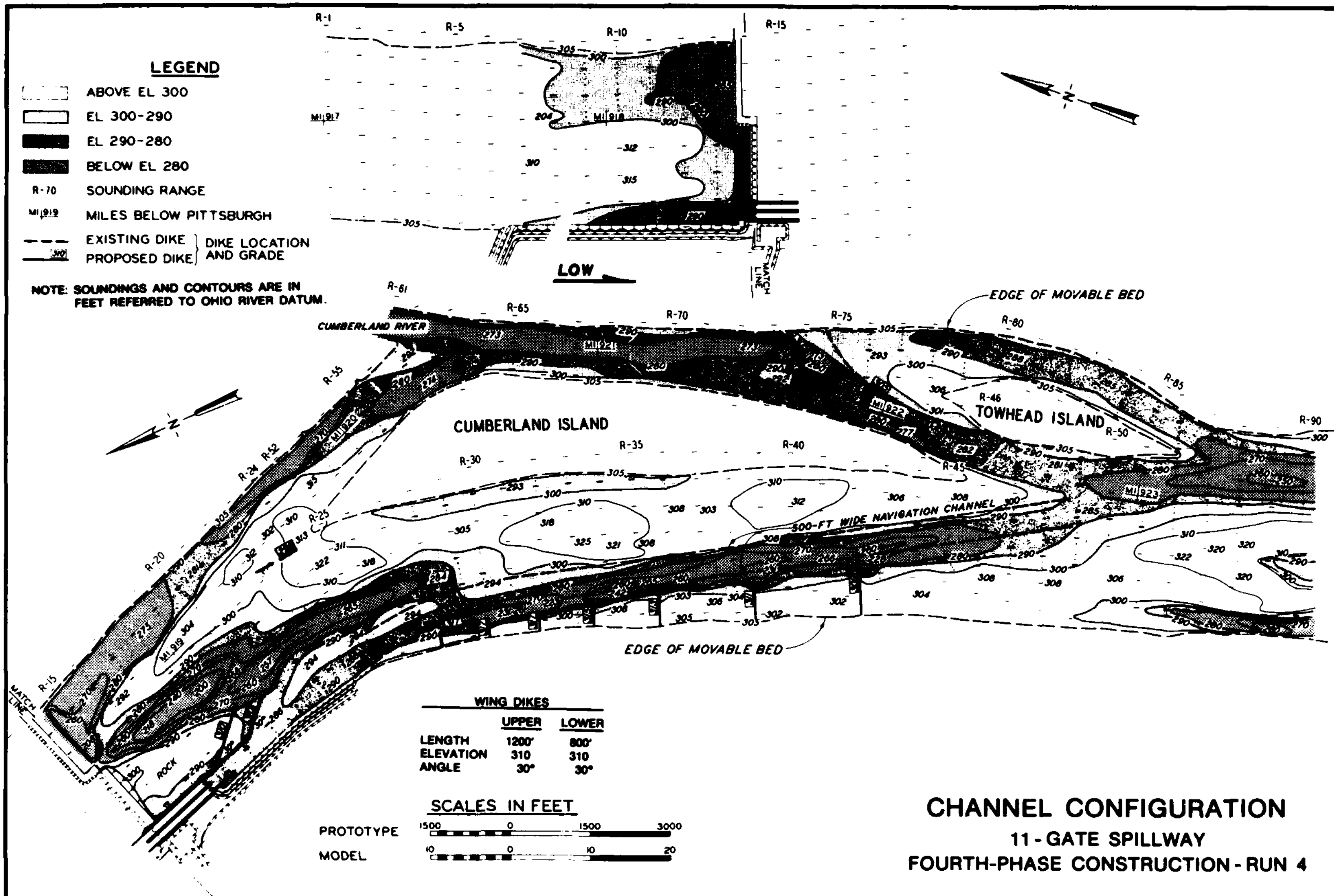

CHANNEL CONFIGURATION
11-GATE SPILLWAY
FOURTH-PHASE CONSTRUCTION - RUN 3
LEGEND
ABOVE EL 300
EL 300-290
EL 290-280
BELOW EL 280
R-70 SOUNDING RANGE
MI 919 MILES BELOW PITTSBURGH
EXISTING DIKE
PROPOSED DIKE
DIKE LOCATION AND GRADE
NOTE: SOUNDINGS AND CONTOURS ARE IN FEET REFERRED TO OHIO RIVER DATUM.
WING DIKES
UPPER
LOWER
LENGTH 1200' 800'
ELEVATION 310 310
ANGLE 30° 30°
SCALES IN FEET
PROTOTYPE
MODEL
CUMBERLAND ISLAND
TOWHEAD ISLAND
CUMBERLAND RIVER
500-FT WIDE NAVIGATION CHANNEL
EDGE OF MOVABLE BED
FLOW
MATCH LINE

PLATE 42



CHANNEL CONFIGURATION
11-GATE SPILLWAY
FOURTH-PHASE CONSTRUCTION-RUN 4

PLATE 43

FILMED

02 — 84